This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

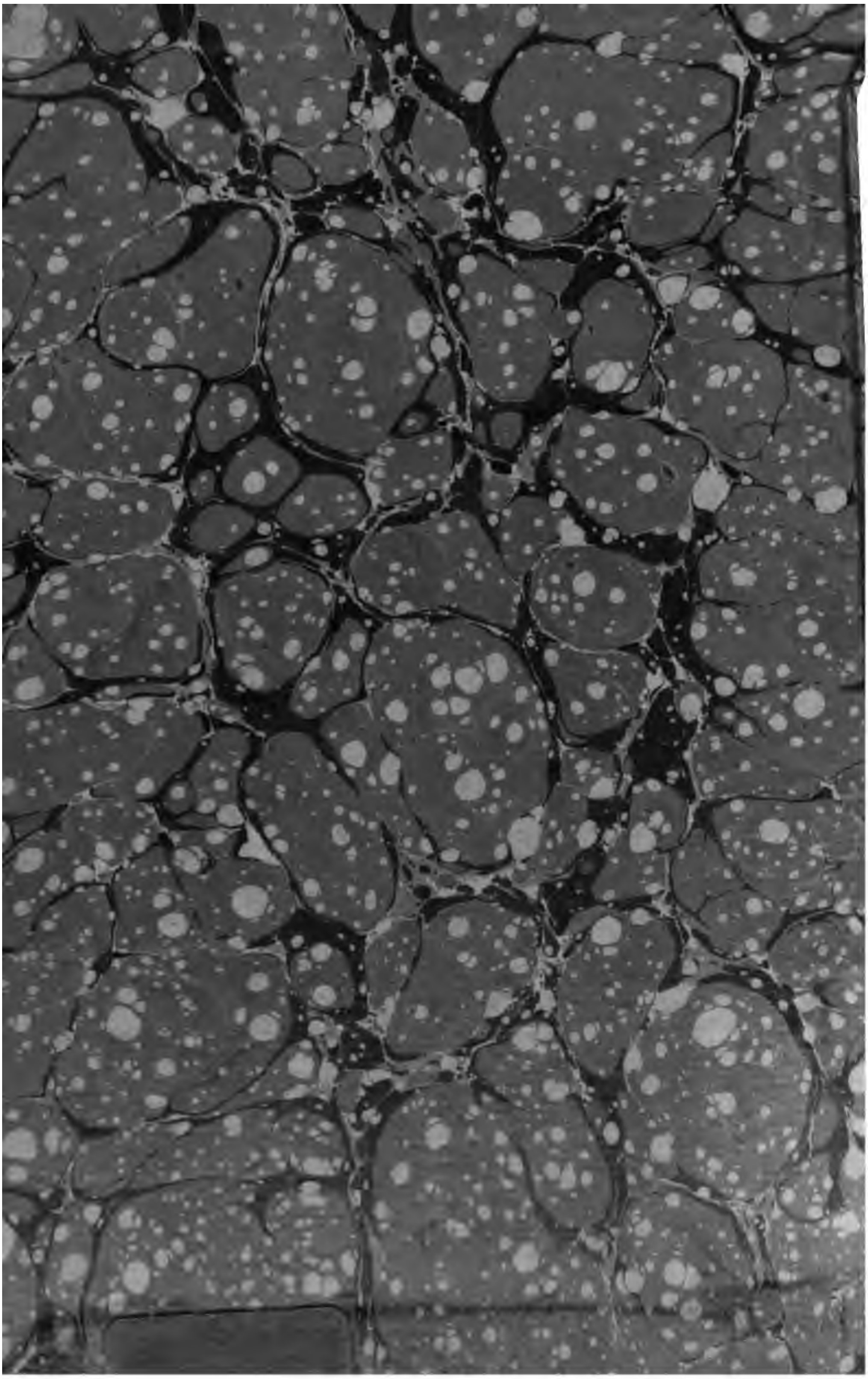
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

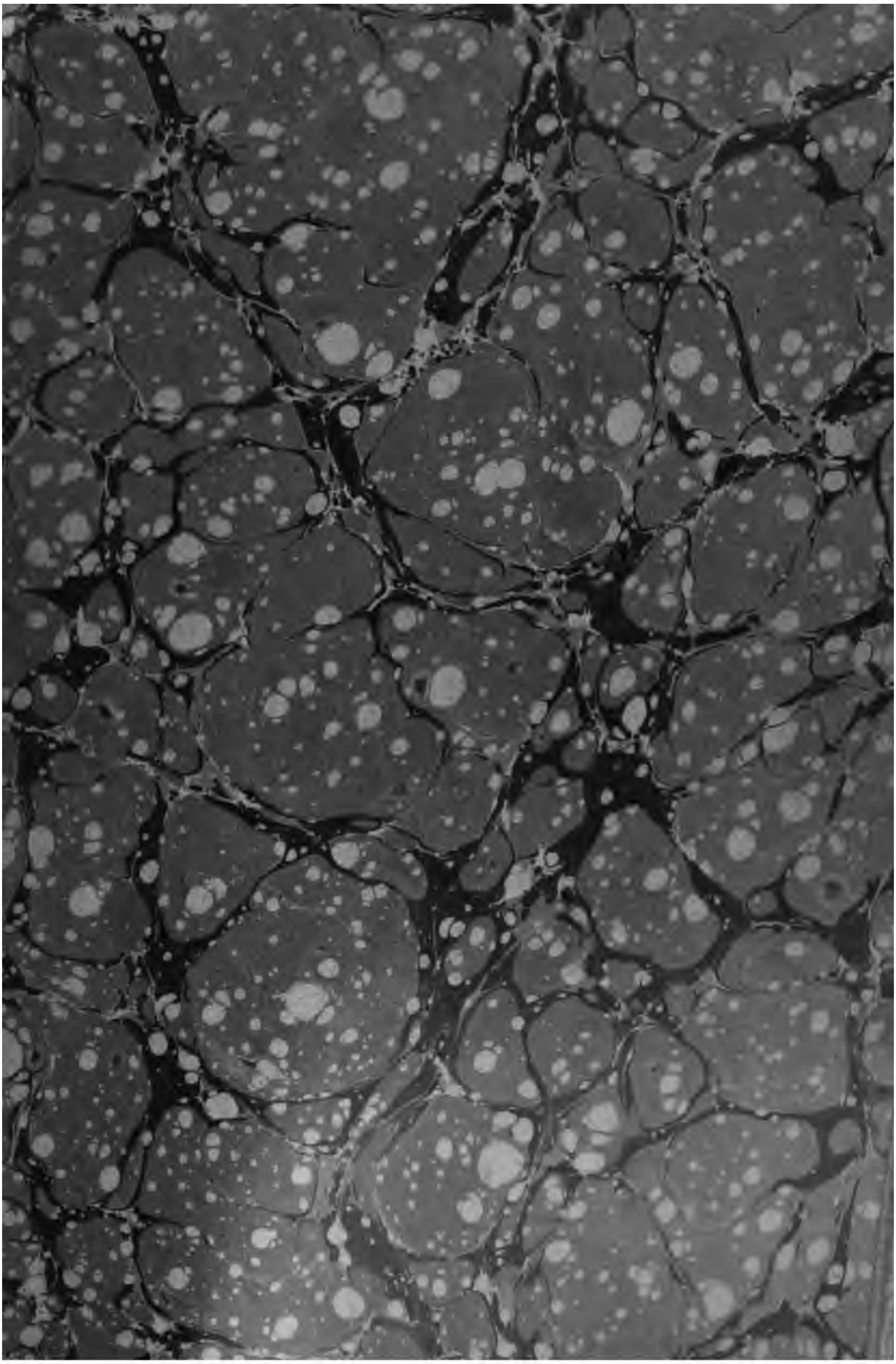
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`





PUBLICATIONS

OF THE

FIELD COLUMBIAN MUSEUM

GEOLOGICAL SERIES.

VOLUME II.

LIBRARY
LELAND [illegible] JUNIOR
[illegible]

CHICAGO, U. S. A.
1903–1907.

136206

TABLE OF CONTENTS.

PAGE

North American Plesiosaurs. Part I.
S. W. Williston. (Plates I-XXIX.)............................... 1- 77

Catalogue of the Collection of Meteorites, May, 1903.
O. C. Farrington. (Plates XXX-XXXIX.)........................ 79-124

On the Osteology of Nyctosaurus (Nyctodactylus), with notes on American Pterosaurs.
S. W. Williston. (Plates XL-XLIV.)............................. 125-163

Structure and Relationships of Opisthocoelian Dinosaurs. Part I, Apatosaurus Marsh.
E. S. Riggs. (Plates XLV-LIII.)................................. 165-196

Observations on the Geology and Geography of western Mexico, including an account of the Cerro Mercado.
O. C. Farrington. (Plates LIV-LXX.)............................ 197-228

Structure and Relationships of Opisthocoelian Dinosaurs. Part II, The Brachiosauridæ.
E. S. Riggs. (Plates LXXI-LXXV.)............................. 229-247

The Carapace and Plastron of Basilemys sinuosus, a new Fossil Tortoise from the Laramie Beds of Montana.
E. S. Riggs. (Plates LXXVI-LXXVIII.)......................... 249-256

A List of Devonian Fossils collected in Western New York, with notes on their Stratigraphic Distribution.
A. W. Slocom. (Plates LXXIX-LXXX.)......................... 257-265

Hypsocrinus, a new genus of Crinoids from the Devonian.
Frank Springer and A. W. Slocom. (Plate LXXXI.).............. 267-271

New Crinoids from the Chicago Area.
A. W. Slocom. (Plates LXXXII-LXXXVII.).................... 273-306

INDEX.

GEOLOGICAL SERIES, VOLUME II.

PAGE

- Achradocrinus 287
  - patulus, 288
- Age of Cerro Mercado, 226
- Analysis of—Dellenose, 224
  - Lassenose, 205
  - Liparose, 222
  - Martite, 215
  - Rhyolite, 205, 222, 223
- Amphicoelias, Relationships of, 241
- Apatite of Cerro Mercado, 217
- Apatomerus mirus, 160
- Apatosaurus, 165
  - Description of skeleton of, 172
  - Restoration of, 195
  - Synonomy of, 170
- Basilemys sinuosus, Carapace and Plastron of, 249
  - Measurements of, 256
- Bather, F. A., quoted, 280
- Birkinbine, John, quoted, 213
- Brachiosauridae, Family characters of, 229
- Brachiosaurus, Description of skeleton of, 229
  - Probable habits of, 244
  - Relationships of, 241
- Carapace of Basilemys sinuosus, 249
- Casts of Meteorites, Catalogue of, 122
- Catalogue and Bibliography of North American Plesiosaurs, 7
- Catalogue of the Collection of Meteorites, May, 1903, 79
- Cerro Mercado, Description of, 210
  - Age of, 226
  - Origin of, 225
- Chicago Area, New Crinoids of, 304
- Chicago Outlet, The 274
- Chrustschoff, quoted, 210, 218, 226
- Cimoliasaurus snowii, 52
- Ciudad de Rocas, Description of, 200
- Classification of Crinoids, 275
- Clay pockets, Fossils found in, 273
  - In limestone, 273
- Cleland, H. F., quoted, 261
- Cope, E. D., quoted, 255
- Crinoids of the Chicago Area, Complete list of, 304
- Crotalocrinus cora, 292
- Dellenose, Analysis of, 224

PAGE
Devonian fossils collected in western New York, 267
Dinosaurs, Opisthocoelian, Structure and relationships of,
  Part I 165
  Part II 229
Distribution of species of Devonian fossils, 262
Dolichorhynchops, 14
  osborni, 13
Durango City, Vicinity of, 198
East Bethany, N. Y., Outcrops at, 258
Eaton, G. F., quoted, 161, 162
Erosion forms, 201
Eucalyptocrinus obconicus, 301
Family characters of the Brachiosauridae, 229
Farrington, O. C., author,
  Catalogue of the Collection of Meteorites, May 1, 1903, 79
  Observations on the Geology and Geography of western Mexico, including an account of the Cerro Mercado, 197
Food habits of Plesiosaurs, 75
Fossils found in clay pockets, 273
Fossils of Lemont Area, 274
Furbringer, quoted, 127
Gilbert, G. K., quoted, 201
Grabau, A. W., quoted, 261
Habrocrinus, 293
  benedicti, 295
  farringtoni, 296
  howardi, 295
  lemontensis, 297
  ornatus, 296
Hall, James, quoted, 289
Haplocanthosaurus, Relationships of, 241
Hatcher, J. B., quoted, 181, 182
Hematite of Cerro Mercado, 211
Hicks, L. E., quoted, 201
Homocrinus, 289
  ancilla, 289
  cylindricus, 291
Hunt, R. W., quoted, 212
Hypsocrinus, 267
  fieldi, 269
Iron Ore of Cerro Mercado, 211
Lambe, L. M., quoted, 253, 255
Lassenose, Analysis of, 205
Lemont Area, Fossils of, 274
Liparose, Analysis of, 222
Lucas, F. A., quoted, 161
Lumholtz, Carl, quoted, 209
Luther, D. D., quoted, 257
Magnetite of Cerro Mercado, 210
Marsh, O. C., quoted, 144, 155, 156, 181

PAGE
Martite of Cerro Mercado, ... 215
  Analysis of, ... 216
Meek, S. E., quoted, ... 198
Meteorites, Catalogue of casts of, ... 122
  Catalogue of the Collection, May, 1903, ... 79
  Micro-sections of, ... 124
Mexico, Geology and Geography of western, ... 197
Micro-sections of meteorites, List of, ... 124
Miller, S. A., quoted, ... 286
Monroe, C. E., quoted, ... 259
Morphology of the Opisthocoelian sacrum, ... 180
Moscow, N. Y., Outcrop at, ... 258
New Crinoids from the Chicago Area, ... 273
Nichols, H. W., Analyses by, ... 205, 216, 222, 224
North American Plesiosaurs, Part I, ... 1
Notes on American Pterosaurs, ... 125
Nyctosaurus, Osteology of, ... 125
  Systematic position of, ... 153
Nyctosaurus gracilis, ... 157
Observations on the Geology and Geography of western Mexico including an account of the Cerro Mercado, ... 197
Oehlert, M. D., quoted, ... 268
Opisthocoelia, Synonomy of, ... 166
  Probable habits of, ... 244
Opisthocoelian Dinosaurs, Key to, ... 229
Opisthocoelian Dinosaurs, Structure and Relationships of,
  Part I. Apatosaurus, ... 165
  Part II. Brachiosauridae, ... 229
Opisthocoelian sacrum, Morphology of, ... 180
Ordoñez, E., quoted, ... 225, 226
Origin of Cerro Mercado, ... 225
Osborn, H. F., quoted, ... 181, 182
Osteology of Nyctosaurus, ... 125
Owen, Richard, quoted, ... 127, 131, 139, 167
Periechocrinus, ... 294
Pionocrinus, ... 293, 294
Pisocrinus, ... 278
  benedicti, ... 279
  gemmiformis, ... 278
  quinquelobus, ... 280
Platycrinus augusta, ... 292
Plesiosaurs, Catalogue and Bibliography of, ... 7
  North American, Part I, ... 1
  Peculiar food habits of, ... 75
  Propodial bones of, ... 73
Plesiosaurus gouldii, ... 72
Plieninger, quoted, ... 131
Polycotylus ischiadicus, ... 72
  latipinnis, ... 67
Propodial bones of young Plesiosaurs, ... 73

PAGE
Prosser, C. S., quoted, ... 257
Pteranodon, ... 129, 161
  gracilis, ... 157
  ingens, Femur of, ... 150
Pterosaurs, Notes on, ... 125
Rangel, M. F., quoted, ... 211
Relations of—Amphicoelias, ... 241
  Brachiosaurus, ... 241
  Haplocanthosaurus, ... 241
Restoration of Apatosaurus, ... 195
Rhamphorhynchus longicaudatus, Vertebrae of, ... 130
Rhyolite, Analyses of, ... 205, 222, 224
  Breccias of, ... 220, 221
Riggs, E. S., author,
  Carapace and Plastron of Basilemys sinuosus, a new Fossil Tortoise from the Laramie Beds of Montana, ... 249
  Structure and Relationships of Opisthocoelian Dinosaurs,
    Part I. Apatosaurus, ... 165
    Part II. The Brachiosauridae, ... 229
Romeo, Illinois, Quarry, ... 273
Schultze, L., quoted, ... 268, 287
Seeley, quoted, ... 144, 149
Sierra Madre, Climate of, ... 209
  Observations on, ... 197
Silver Ore, of Ventanas, ... 208
Slocom, A. W., author,
  A List of Devonian Fossils collected in western New York, with notes on their Stratigraphic Distribution, ... 257
  New Crinoids from the Chicago Area, ... 273
Slocom, A. W. and Springer, Frank, authors.
  Hypsocrinus, a New Genus of Crinoids from the Devonian, . . . 267
Shimer and Grabau, quoted, ... 257
Springer, Frank, and Slocom, A. W., authors,
  Hypsocrinus, a New Genus of Crinoids from the Devonian, . . . 267
Stephanocrinus, ... 281
  obconicus, ... 281
  skiffi, ... 282
Stratigraphic distribution of Devonian fossils, ... 257
Structure and Relationships of Opisthocoelian Dinosaurs,
  Part I. Apatosaurus, ... 165
  Part II. Brachiosauridae, ... 229
Terminology of Crinoids, ... 275
Terrestrial Nickel-Irons, List of, ... 121
Thysanocrinus, ... 299
  campanulatus, ... 299
Ventanas, Mexico, ... 208
Von Ammon, quoted, ... 130, 138
Von Meyer, quoted, ... 138
Weed, W. H., quoted, ... 198
Weidner, Federico, quoted, ... 210, 226

PAGE
Weller, Stuart, quoted, ... 299
Williston, S. W., author,
    North American Plesiosaurs, Part I, ... 1
    On the Osteology of Nyctosaurus, with Notes on American Pterosaurs, 125
Williston, S. W., quoted, ... 180, 181
Windom, N. Y., Outcrop at, ... 259
Witherbee, T. F., quoted, ... 210, 211, 212, 213, 219, 227
Zophocrinus, ... 284
    globosus, ... 285
    howardi, ... 286
    pyriformis, ... 285

FIELD COLUMBIAN MUSEUM.

PUBLICATION 73.

GEOLOGICAL SERIES. VOL. II, NO. 1.

NORTH AMERICAN PLESIOSAURS.

PART I.

BY

SAMUEL W. WILLISTON, M.D., PH.D.,
Associate Curator, Division of Palæontology;
Professor of Palæontology, University of Chicago.

OLIVER C. FARRINGTON, PH. D.,
Curator of Geology.

CHICAGO, U. S. A.
April, 1903.

NORTH AMERICAN PLESIOSAURS.

PART I.

BY SAMUEL W. WILLISTON.

CONTENTS.

PAGE

Introduction, ... 3

Bibliography and catalogue of North American Plesiosaurs, ... 7

Dolichorhynchops osborni Williston. Description of skeleton, with restoration, ... 13

Cimoliasaurus snowii Williston. Description of skull and neck, . . . 52

Brachauchenius lucasii Williston. Description of skull, vertebræ and ribs, 57

Polycotylus latipinnis Cope. Description of paddle, ... 67

Polycotylus ischiadicus Williston. Description of pelvis, ... 72

Plesiosaurus gouldii Williston. Description of dorsal vertebra, . . . 72

Propodial bones of young Plesiosaurs from the Cretaceous of Kansas, . 73

A peculiar food-habit of the Plesiosaurs, ... 75

Plates I to XXIX, ... 79

INTRODUCTION.

There are few orders of reptiles, so long and so widely known as are the plesiosaurs, of which our knowledge is more unsatisfactory. It has been within the past decade only that a tolerably complete knowledge of any form has been obtained, thanks largely to the researches of Seeley, Dames and Andrews. Especially is our ignorance of the American forms yet great. Very few figures or adequate descriptions have been published of our numerous and diverse types. Not only are the specific characters of the descriptions almost wholly undecipherable, but the generic characters even can be satisfactorily made out in but few. Thirty-two species and fifteen genera have been described from the United States, and in not a single one of them has there been even a considerable part of the skeleton made known. The skull is known in but three species, and in only one has there been any description of it. With the exception of a sketch of the incomplete girdles of *Elasmosaurus platyurus*, and of a few limb bones by Leidy, with an outline figure of a *Megalneusaurus* paddle by Knight, nothing of the extremities has been published. And yet, specimens of plesiosaurs are not at all rare in American deposits and collections.

Although most of the genera and species of the United States have been founded on such scant material, and even more scanty descriptions, that their identification is almost impossible, except by actual comparison of the type specimens, it is not at all improbable that nearly all the names which have been proposed will eventually be found valid. The group has a wide geological range, from the Jurassic to the uppermost Cretaceous, nearly every epoch being represented by one or more species.

The writer has for some time given such attention as his duties permitted to the study of the American plesiosaurs, in the hopes eventually of clearing up much of the confusion now existing concerning these animals, and the present paper was intended to be published as a portion of this monographic study. As, however, the publication of so extensive a paper must be deferred for some time, he has thought best to publish that portion now prepared in advance of a more final review of the subject. The present paper contains detailed descriptions of *Dolichorhynchops osborni* Williston and *Brachauchenius lucasi* Williston; a revised description of *Cimoliasaurus snowii* Williston, together with certain descriptions of and remarks upon such other forms from the Kansas Cretaceous as bear more or less directly upon the principal species here discussed. As will be seen from the list given below, no less than nine distinct species of plesiosaurs have been described from the Kansas Cretaceous, all of which, except one or two, are autoptically more or less known to the writer, together with nearly as many more hitherto undescribed. The true generic determination of the most of these species is impossible at present. So little is known of the real generic characters, not only of the American but also of the European plesiosaurs, that, unless specimens are very complete, it is impossible to correctly assign them. Furthermore, there is in many respects such wide diversity between the different forms now known that almost every species seems rightfully to belong in a different genus. On the other hand, in our present ignorance of their value, generic differences can rarely be recognized unless one has a considerable portion of the skeleton. Generic determination is, therefore, for the most part, at the present time simply guess-work. In the present paper I have, for convenience sake, given names to some of these new forms, but the generic names are always provisional, and the specific names also in some cases. *Cimoliasaurus snowii* I do not believe is congeneric with the type species of the genus; it belongs as well in several other genera proposed by American writers. I do not see, however, much use in giving new generic names to every form until some *raison d'être* can be discovered for them. I have departed from this conviction in proposing two new generic names for species herewith described, largely because the specimens upon which the names are based are more than usually complete, and because there seems to be positive characters to sustain the names.

The full description and illustration of *Dolichorhynchops osborni* will, I trust, aid in the solution of many of these generic problems; they will at least furnish a means of comparison for other forms known already or to be discovered in the future.

A second part of this work is to follow soon, I trust. It will contain the descriptions and illustrations of two or three other skulls, different in structure from those herewith described and from each other, together with other important material.

I am glad to express my thanks to Prof. Dr. E. Fraas for kind suggestions, and for the communication of photographs; and to Prof. H. F. Osborn for kind favors.

Seeley* has proposed to divide the plesiosaurs into two chief groups, the Dicranopleura, including those forms with double-headed ribs in the cervical region, both long-necked (Dolichodeira) and short-necked (Brachydeira); and of which singularly no certain representatives have been discovered in America; and the Cercidopleura, those with single-headed ribs, also including both long-necked and short-necked types. Cope in 1887† proposed the two sub-families: *Polycotylinæ* for those with broad epipodial bones; and the *Plesiosaurinæ* for those with elongated epipodial bones, of which there are no certain representatives in America. But objections may be urged against both of these classifications. Certain forms very closely allied to *Pliosaurus*, a dicranopleuran, have single-headed ribs throughout. *Polycotylus* is a short-necked type, with single-headed cervical ribs, and it seems almost certain that certain long-necked forms that should be widely separated have also broad epipodial bones.

Nevertheless, I feel pretty confident that the final classification of the Plesiosauria will include three or four distinct families and twenty or thirty well-defined genera. There is scarcely a group of extinct reptiles, unless it be the Dinosauria, which offers more divergent characters than do the plesiosaurs. The skull may be long and slender or short and broad; the teeth irregular in size and large, or small and nearly uniform; the prefrontals and postorbitals separated or suturally united; the parietals with a high thin crest, or without such a crest; the palatines widely separated or broadly contiguous; the supraöccipitals paired or single(?). The neck may include as few as thirteen vertebræ or as many as seventy-two, the vertebræ all very short or the posterior ones elongated; the ribs single or double-headed; the arches anchylosed to the centra or suturally free throughout life. The dorsal vertebræ may be no longer than the anterior cervicals or much elongated; all the vertebræ may have conspicuous vascular foramina below or be without them; the diapophyses may be much elongated and situated low down, or shorter and situated high up; the vertebral spines elongated or short. In the pectoral girdle there may be a long epicoracoidal process; the clavicles and episternum either present or absent. The epipodial bones are two in number and elongated, or three or four and broad. The ilium may differ in its mode of attachment and the form of both pubis and ischium may differ much.

---

* Proc. Royal Soc. Lond. 1892, 151.

† American Naturalist, 1887, 564.

Certainly among all these characters, and probably not a few others, there will be no dearth of material for classification. Unfortunately there are yet many forms in which we do not know what relations these different characters bear to each other, and until we do, any classification must be provisional. I believe that most herpetological taxonomists will agree with me that the differences between *Dolichorhynchops* and *Brachauchenius* are more than generic in value, and I doubt not that differences of equal value will be discovered in yet other species when we shall know more about them than we do at present.

The origin of the Plesiosauria I will discuss in a later paper. For the present, I may say that I believe that their nearest affinities among all reptiles, recent or extinct, are with the Dicynodonts.

CATALOGUE AND BIBLIOGRAPHY OF THE NORTH AMERICAN PLESIOSAURIA.

PLESIOSAURUS.

Conybeare, Trans. Geol. Soc. Lond. v, 560, 1821.

BREVIFEMUR Cope, Cret. Vertebr. 256, 1875.—Greensand No. 5, New Jersey.

Cimoliasaurus magnus (Leidy) Cope, Ext. Batrach. 1869, 43, ff. 13–15.

***GULO** Cope, Proc. Acad. Nat. Sci. Phil. 1872, 228; Cret. Vert. 1875, 256.—Fort Pierre Cretaceous, Kansas (*errore*, Niobrara).

***MUDGEI** Cragin, Fifth Pub. Colorado Col. Sci. Soc. 69, ff. 1–3.—Comanche Cretaceous, Kansas.

***GOULDII** Williston, Kansas Univ. Quart. vi, 57, 1897.—Comanche Cretaceous, Kansas.

SHIRLEYENSIS Knight, Amer. Journ. Sci. 1900, p. 115.—Jurassic, Wyoming.

All of the foregoing species were based upon fragmentary material, and it is improbable that any belong in the genus *Plesiosaurus*.

CIMOLIASAURUS.

Leidy, Proc. Acad. Nat. Sci. Phil. 1851, 325 (1852).

MAGNUS Leidy, l. c.; ibid. 1854, 72, pl. ii, ff. 4–6; Cretac. Rept. 1865, 25, pl. v, ff. 13–19, pl. vi; Cope, Ext. Batrachia, etc. 1869, 42; Lydekker, Cat. Fos. Rept. Brit. Mus. 11, 211.—Cretaceous No. 5, New Jersey.

PLANIOR Leidy, Proc. Acad. Nat. Sci. Phil. 1870, 22.—Cretaceous, New Jersey (see also *Discosaurus*).

***SNOWII** Williston, Science, xvi, 262; Trans. Kansas Acad. Sci. xii, 174, 1890; Cope, Proc. Amer. Phil. Soc. xxxiii, 109.—Niobrara Cretaceous, Kansas.

LARAMIENSIS Knight, Amer. Jour. Sci. x, 117, 119.—Jurassic, Wyoming.

This genus was based upon vertebral centra alone, from the cervical, dorsal and caudal regions; the author, however, referred them all erroneously to the dorsal and lumbar regions. The type is well figured in Leidy's work on Cretaceous Reptiles, plates v and vi. The vertebræ have infracentral vascular foramina. The ribs are single-headed. The largest centrum measures 110 millimeters in the greatest diameter. This genus has served as a sort of waste basket for the reception of fragments and poorly known forms. *C. snowii* is known from a skull and long neck. It can scarcely belong in *Cimoliasaurus*.

DISCOSAURUS.

Leidy, Proc. Acad. Nat. Sci. Phil. 1851, 326 (1852).

PLANIOR Leidy, Proc. Acad. Nat. Sci. Phil. 1870, 20, 22; Cope, Cretac. Vert. 1875, 255 (*Cimoliasaurus*).—Cretaceous, Mississippi.

Discosaurus vetustus Leidy, Cretac. Reptilia, 23, pl. 5, ff. 10–12.

VETUSTUS Leidy, Cretac. Reptilia, 22, pl. iv, ff. 13-18, pl. v, ff. 1–9; Proc. Acad. Nat. Sci. Phil. 1851, 326; Cope, Ext. Batrachia etc. 256; Amer. Journ. Sci. 1870, 141; Cretac. Vert. 1875, 255 (*Cimoliasaurus*).—Cretaceous, Alabama.

This genus was based upon the mutilated bodies of two caudal vertebræ from the Cretaceous of Alabama. Leidy associated with these other mutilated vertebræ from the Cretaceous of Mississippi, New Jersey and Alabama. Cope suppressed the name, as of a genus insufficiently differentiated from *Cimoliasaurus*. This is quite true, as it is also true of several of Cope's own genera of the plesiosaurs. It is not at all improbable, however, that there are different species, and perhaps different genera represented by the specimens Leidy described and figured.

BRIMOSAURUS.

Leidy, Proc. Acad. Nat. Sci. Phil. 1854, 73.

GRANDIS Leidy, Proc. Acad. Nat. Sci. Phil. 1854, 73, pl. i, ff. 1–3; ibid. 1870, 10: ibid. 1871, 22 (*Discosaurus*): Cope, Ext. Batrachia, etc. 1869, 43, 54 (*Cimoliasaurus*); Proc. Bost. Soc. Nat. Hist. 1869. 266 (*id.*); Amer. Journ. Sci. 1870, 269 (*id.*), Rep. Geol. Surv. Terr. 1871, 400 (*id.*); Cretac. Vert. 1875, 255 (*id.*)—Cretaceous, Arkansas.

This genus and species were founded upon more or less imperfect dorsal vertebræ from the Cretaceous, probably Benton, of Clark County, Arkansas. Cope suppressed the generic name as of a genus not sufficiently differentiated from *Cimoliasaurus*. I believe, however, that both genus and species are valid; and that the former will include some of the species from Kansas. Lambe has identified the species from the Belly River Cretaceous of Canada, but it seems to me that the identity must be more or less problematical.

ELASMOSAURUS.

Cope, Proc. Acad. Nat. Sci. Phil. 1868, 68.

*PLATYURUS Cope, l. c.; Notes on Geology, Leconte, 1868, 68; Proc. Bost. Soc. Nat. Hist. 1869, 266; Amer. Nat. iii, 87; Ext. Batrachia, etc. 1869, 47, ff. 7–12, pl. ii, ff. 1–9, pl. iii: Amer. Jour. Sci. 1870, 140, 268; Amer. Nat. v, 47; Rep. U. S. Geol. Surv. Terr. 1871, 393, 1872, 320, 336; Cretac. Vert. 1875, 44, 79, 256; Bull. U. S. Geol. Surv. Terr. iii, 1877, 578; Amer. Nat. xxii, 724; Leidy, Amer. Jour. Sci. xlix, 1870, 392; Proc. Acad. Nat. Sci. Phil. 1870, 9, 18; Lydekker, Cat. Foss. Rept. Brit. Museum, ii, 181 (*Cimoliasaurus*).—Fort Pierre Cretaceous, Kansas.

INTERMEDIUS Cope, Proc. Amer. Phil. Soc. 1894, 112.—Fort Pierre Cretaceous, South Dakota.

ORIENTALIS Cope, Proc. Acad. Nat. Sci. Phil. 1868, 313; Proc. Bost. Soc. Nat. Hist 1869, 266; Geological Surv. New Jersey, Cook, Append. (1868), 1869, 733; Amer. Nat. 1869, 87; Ext. Batrachia, etc. 1869, 44, 55, pl. ii, f. 10; Amer. Jour. Sci. 1870, 368; Cretac. Vert. 1875, 255; Bull. U. S. Geol. Surv. Terr. iii, 1877, 567, 578; Am. Nat. xi, 1877, 311; Leidy, Proc. Acad. Nat. Sci. Phil. 1870, 22 (*Discosaurus*).—Greensand No. 4, New Jersey.

SERPENTINUS Cope, Bull. U. S. Geol. Surv. Terr. iii, 578, 1877; Amer. Nat. xi, 1877, 311.—Niobrara Cretaceous, Nebraska.

The genus *Elasmosaurus* was founded upon a nearly complete series of vertebræ obtained near the vicinity of Fort Wallace, Kansas, wrongly ascribed to the Niobrara epoch. The neck was very long. The incomplete girdles are also known. No additional material has been ascribed to the type species since the original description by Cope.

POLYCOTYLUS.

Cope, Proc. Amer. Phil. Soc. xi, 117, 1869.

*LATIPINNIS Cope, l. c.; Ext. Batrachia, etc. 36, pl. 1, ff. 1–12; An. Rep. U. S. Geol. Surv. 1871, 388; ibid. 1872, 320, 335; Bull. U. S. Geol. Surv. Terr. 27, 1874; Cretac. Vertebrata, 45, 72, 255, 1, vii, ff. 7, 7a; Leidy, Ext. Vert. Fauna, 279.—Niobrara Cretaceous of Kansas.

*ISCHIADICUS Williston, posteà, Niobrara Cretaceous, Kansas.

This genus was based upon a portion of a propodial bone and imperfect cervical and dorsal vertebræ. The ribs of the neck are single-headed.

PIRATOSAURUS.

Leidy, Cretaceous Rept. N. Amer. p. 29, 1865.

PLICATUS Leidy, l. c. pl. xix, fig. 8.—Cretaceous, Minnesota.

Based upon a single tooth. Believed by the author to be Crocodilian. The horizon is probably Niobrara, judging from the accompanying fossils. If so, it would seem very probable that the tooth belongs to a plesiosaur, though rather sharply conical in shape.

NOTHOSAUROPS.

Leidy, Proc. Acad. Nat. Sci. Phil. 1870, 74.

OCCIDUUS Leidy, l. c.; Rep. Geol. Surv. Terr. 1873, i, 345, pl. xv, ff. 11–23; Cope, Bull. U. S. Geol. Surv. Terr. i, 28, 1874 (*Plesiosaurus*); Cretac. Vert. 1875, 256 (*id.*).—Laramie [?] Cretaceous, Dakota.

TAPHROSAURUS.

Cope, Proc. Amer. Phil. Soc. xi, 274, 1870.

LOCKWOODI Cope, Ext. Batrachia, etc. 1869, 40 (*Plesiosaurus*); Proc. Amer. Phil. Soc. xi, 274.—Cretaceous No. 1, New Jersey.

OLIGOSIMUS.

Leidy, Proc. Acad. Nat. Sci. Phil. 1872, 39 (1873).

GRANDÆVUS Leidy, l. c. 40; Extinct Vert. Fauna, 286, 345, pl. xvi, ff. 18, 19.—

This genus and species were proposed for a detached caudal vertebra of small size, without definite horizon, from Green River, Wyoming. The processes are attached. The description will apply to caudal vertebræ of various genera.

URONAUTES.

Cope, Proc. Acad. Nat. Sci. Phil. 1876, 345.

CETIFORMIS Cope, l. c. 346.—Fort Pierre (?) Cretaceous, Montana.

SPECIES Cope, Amer. Nat. 1887, 566.—Fox Hills Cretaceous, New Mexico.

This genus was based upon cervical, dorsal and caudal vertebræ. The cervicals are short, with the processes partly attached, and the ribs single-headed.

Professor Cope referred the type species to the Fox Hills Cretaceous with doubt. I suspect, rather, that the horizon is Fort Pierre.

OROPHOSAURUS.

Cope, Amer. Naturalist, 1887, 564.

PAUCIPORUS Cope, l. c.—Fox Hills Cretaceous of New Mexico.

Based upon parts of three cervical vertebræ. The neural arches are coössified, the ribs free. Centra short; ribs single-headed.

PIPTOMERUS.

Cope, Amer. Nat. 1867, 564.

MEGALOPORUS Cope, l. c. 564.—Fox Hills Cretaceous, New Mexico.

MICROPORUS Cope, l. c.—Fox Hills Cretaceous, New Mexico.

HEXAGONUS Cope, l. c.—Fox Hills Cretaceous, New Mexico.

This genus and species are based upon cervical and dorsal vertebræ only. The cervicals are short, the processes free and the ribs single-headed.

TRINACROMERUM.

Cragin, Amer. Geologist, Dec. 1888.

*BENTONIANUM Cragin, l. c.; ibid. 1891, 171.—Benton Cretaceous, Kansas.

A large part of the skeleton was known to the describer, including the skull, vertebræ, part of the girdles and limbs.

PANTOSAURUS.

Marsh, Report Geological Congress, 1891, 159; Amer. Journ. Sci. xli, 1895, 406: *Parasaurus* Marsh, Amer. Journ. Sci. xliii, 338, 1891 (preoccupied).

STRIATUS Marsh, Amer. Journ. Sci. xliii, 338, 1891 (*Parasaurus*); ibid, i, 406, 1895, ff.—Baptanodon Beds, Wyoming.

Based upon a posterior cervical centrum. "Vertebræ strongly grooved. Neck long and slender, the vertebræ preserved resemble most in form and size those of *Plesiosaurus plicatus* Phillips."

EMBAPHIAS.

Cope, Proc. Amer. Phil. Soc. 1894, 111.

CIRCULOSUS Cope, l. c.—Pierre Cretaceous, South Dakota.

This genus and species were founded on three vertebræ, cervical and dorsal. The cervicals are short, with persistent sutures. Ribs double-headed(?).

MEGALNEUSAURUS.

Knight, Amer. Journ. Sci. v, 1898, 375.

REX Knight, Science, 1895, 449 (*Cimoliasaurus*); Amer. Journ. Sci. v. 1898, 379, ff. 1 3.- -Jurassic, Wyoming.

A large portion of the skeleton of the type species is known; the parts so far described are the vertebræ and limbs.

DOLICHORHYNCHOPS.

Williston, Kansas Univ. Sci. Bulletin, No. 9, p. 141. Sept. 1902.

*OSBORNI Williston, l. c.—Niobrara Cretaceous, Kansas.

BRACHAUCHENIUS.

Williston, posteà.

*LUCASI Williston, posteà.—Benton Cretaceous, Kansas.

DOLICHORHYNCHOPS OSBORNI.

The specimen of *Dolichorhynchops osborni* herewith described and illustrated was discovered by Mr. George Sternberg in the chalk of Logan County, Kansas, in the summer of 1900, and skilfully collected by his father, Mr. Chas. H. Sternberg, the veteran collector of fossil vertebrates. The specimen was purchased of Mr. Sternberg in the following spring for the University of Kansas, where it has been mounted and where it now is. When received at the museum the skeleton was almost wholly contained in a large slab of soft yellow chalk, with all its bones disassociated and more or less entangled together. The left ischium, lying by the side of the maxilla, was protruding from the surface, and a part of it was lost. The bones of the tail and some of the smaller podial bones were removed a little distance from the rest of the skeleton, and were collected separately by Mr. Sternberg. The head was lying partly upon its left side and some of the bones of the right side had been macerated away; the maxilla indeed had disappeared.

The task of removing and mounting the bones has required the labor of Mr. H. T. Martin the larger part of a year, and is, as finally mounted, an example of great labor and skill on his part. For the position of the bones in the recreated skeleton and their general arrangement I am of course responsible. There is some little doubt as to the exact position of the pectoral girdle, as respects the ribs and vertebræ. The position as shown in the restoration is that which seemed, upon the whole, most nearly the truth, judging from the figured skeletons of *Plesiosaurus*. There is also some doubt about the proper length of the tail. The relations of the preserved centra seemed to indicate a loss of a few vertebræ in this region, and for that reason four plaster models have been intercalated. There are nineteen vertebræ preserved in the neck; there may have been one more, or possibly two, but for reasons discussed further on this is doubtful. In the dorsal region there are thirty vertebræ, three of which may be called pectoral. Twenty-five are preserved in the tail. The skull, after its complete removal from the matrix, was found to be so very fragile that it was not thought expedient to mount it. It was also somewhat distorted, as will be seen from the illustrations. A model, therefore, was made under my careful supervision, and mounted in its stead. The skeleton as mounted is just ten feet in length. The neck in life must have been thick and heavy at the base, tapering rapidly from the trunk to the head. The trunk was broad, as is evident from the position of the ribs, with the under side not flat, as might be supposed, but strongly convex from side to side. The abdominal region proper, between the girdles, must have been short, and could not have been very distensible. The short tail was thick at its base, as is conclusively shown by the attachment of the ilia and the elongated ischia. Furthermore, the fore legs, at least, must have been enclosed for a considerable distance at their attachment by the skin and muscles of the pectoral region; they could not have been pedunculated to the extent that they are usually represented to be in the restorations. The species was named in honor of Prof. H. F. Osborn of Columbia University.

The distinguishing characters, both family and generic, may be summed up as follows:

DOLICHORHYNCHOPS.—*Head elongate, the facial region much attenuated; teeth nearly uniform in size, small; prefrontal and postfrontal bones not joined; parietals extending into a high crest; supraoccipital bones separated; internal nares small, included between the vomer and palatine only; palatines broadly separated throughout; a large vacuity between the pterygoids anteriorly; quadrate process of pterygoids short. Neck but little longer than the head, composed of nineteen or twenty vertebræ: all presacral vertebræ of nearly equal length, moderately concave, and with vascular foramina below: spines short, uniform in length: diapophyses of the dorsal vertebræ situated high up. Coracoids with long epicoracoid process: clavicles and scapulæ free: episternum with an emargination in front and behind, the latter forming part of a large interclavicular foramen. Three epipodial bones, all broader than long. Ischium elongated. Length ten feet.*

SKULL.—The skull of *Dolichorhynchops osborni* is of a remarkably elongate and slender form, attenuated in front of the orbits, and with a thin, high, parietal crest. The region between the eyes is very narrow, the superior temporal vacuities large, and the teeth numerous and slender. The head is more nearly of the typical aquatic fish-eating type than is perhaps known in any other plesiosaur, and the neck is as short as or shorter than in any other plesiosaur hitherto described. The skull, as received, was lying partly upon its left side, with a part of the right side separated and injured, some of the bones having been macerated away. The specimen was completely removed from the matrix, including even that which was between the bones, and the elements of the brain case were separated out. In consequence, the fragility of the skull was such that it was not deemed prudent to mount it with the remainder of the skeleton. A model of it was therefore made, based upon my drawings and studies, and which, I think, represents the skull very nearly as it must have been during life. Its width in all parts may not have been accurately determined, but the discrepancies from the reality can not be great.

The *premaxillaries* are separated from each other distinctly by suture, the long facial processes apparently lying in contact with each other without close union. The suture separating them from the maxilla begins just back of the sixth tooth; it curves upward and backward for a short distance, and then runs parallel with the upper border as far back as the narial opening, whence the margin runs more obliquely to the tip of the processes above the middle of the orbit. Each premaxilla bears six teeth, which are among the largest of the jaws, and are all of nearly uniform size, the first one curved forward. The facial process is slender, flattened on its opposing, sutural surface, and with its external, convex surface distinctly striated longitudinally. The dentigerous portion is convex, pitted toward the anterior part, and about twenty- five millimeters in height, opposite the last tooth. The relations of the bone on the palatal surface can not be determined.

The *maxillæ* are long and narrow on the facial surface, and very narrow on the palatal surface, at least posteriorly. They bear twenty teeth on each side, the first ten or eleven of which are of nearly equal size, and scarcely smaller than those of the premaxillæ. The posterior ten teeth are crowded, occupying a space less than one-half that of the preceding ten, and they are smaller. The greatest width of the maxilla on the facial surface —about twenty-five millimeters—is at about seventy millimeters in front of the orbit, whence the bone narrows to a width of ten millimeters below the anterior border of the orbit. Below the orbit, the bone extends as a narrow bar, becoming slightly narrower posteriorly, before the beginning of the jugal suture. Beyond this, it flattens posteriorly to near its extremity, which is about midway of the temporal bar, and one hundred millimeters beyond the last tooth.

There are twenty-five or twenty-six teeth in each jaw. They are inserted by a long fang, the pulp cavity of which occupies more than one-third of the diameter, extending a short distance into the crown. In the largest teeth, the crown is about twenty millimeters in length, with a diameter at the base of six millimeters. The crown is relatively slender, strongly convex anteriorly, sharply conical, and with slender, delicate, longitudinal striæ, except on the outer, anterior part, where the surface is nearly smooth. The posterior teeth are much smaller, as already stated, and are much more closely placed, their length varying from six to twelve millimeters.

The united *parietals* form a high, thin, vertical plate of bone, convex in outline, about fifty millimeters in height in the middle, and only three or four in thickness at the margin, and extending nearly as far forward as the pineal foramen. Posteriorly, the sides extend downward and outward into a broad flattened process for union with the upper ramus of the squamosal. The suture, which is clearly apparent, runs downward and outward to the free margin of the parietal on each side, beginning in front of the posterior thickened bar of the squamosal. Anteriorly this free margin of the parietal is continued outward, like the eaves of a roof, to the posterior part of the orbit, where it is somewhat roughened; it turns upward here rather abruptly. About twenty millimeters above this angle, separated by a concave space, is the massive projection for the epipterygoid. This bone has been broken away from its attachment on each side, and separated for a short distance, leaving a jagged fracture, without indications of suture. The upper margin of this thickened epipterygoid protuberance is continued by sutural union with the postfrontal. A little in front of the parietal foramen, the bone narrows to a width of four or five millimeters, blended with and continued into the frontal, which continues forward to the premaxillary, under which it disappears. The sutural union for the postfrontal is well marked on the right side, beginning a little back of the pineal foramen and running downward, outward and backward to the upper margin of the epipterygoid protuberance. Internally the parietals form a broad roof, to which is attached, rather far forward, by distinct, oval, obliquely placed, V-shaped articular surfaces, the paired supraoccipitals, which do not reach quite to the lower free margin of the parietals on each side.

Anteriorly, as already stated, the frontal (?) continues, without the slightest indication of a suture with the parietals, forward for forty millimeters or so more, as a narrow, flattened surface above, distinctly divided by a median suture, to the upper end of the facial processes of the premaxillæ, which articulate on the outer side of the slender projection, overlapping the upper surface. How much further the bones continue I can not say, but evidently as far forward as the anterior end of the orbits. On the right side, the "postprefrontonasal" has been macerated away, so that its relations are clearly marked. Below these bones are broader, continuous on each side with the free margin of the roof, as already described. The rostrum formed by the "frontals" is stout and rounded, and is continued at least as far forward as the anterior end of the orbit, clearly separated above and below by the median suture. The anterior ends are lost in front in the broken fragments of bone, between and beyond the anterior end of the orbits. Lying between the orbits, and separated from each other by a narrow interval, are the narrow bones which may represent the conjoined postfrontals and prefrontals and nasals. On the right side, as stated above, the bone had been macerated away. and while some of its processes had been broken off and lost, the sutures for union with the parietal, frontal and prefrontal are beautifully preserved, showing the relation to these bones in a way that precludes doubt. The bone shows no trace of division whatever into its supposed elements. It articulates with the "frontal," parietal, epipterygoid, "postorbital," "supraorbital," premaxilla and maxilla. Posteriorly the bone extends downward, outward and backward to the upper margin of the epipterygoid protuberance; externally and posteriorly it sends off a projection for union with the post-orbital; anteriorly the bone fits into a groove on the outer side of the facial processes of the premaxillaries for a distance of thirty or forty millimeters, and has a stout process on the outer side for union with the supraorbital, or whatever the element may be here. On the under side there is a broad, flattened, vertical plate, continuous from the posterior, inferior angle, and widened in the middle so as to reach the greater part of the way to the upper surface of the palatal bone, forming the inner wall of the orbit in large part. The plate given off for union with the "supraorbital" is separated by a sharp, deep notch from a similar process for union with the "postorbital." The "supraorbital" bone has been crushed back over this process, so that the distinguishing suture can be perceived in one place only, anteriorly. In front of the orbit, the bone sends out a thin, triangular plate, which curves downward to meet the maxillæ, separated from its mate by the premaxillæ. Doubtless this part represents the nasal, and perhaps also the lachrymal, but there are no indications of distinguishing sutures, and I do not believe that the nasal exists as a separate element in the adult plesiosaur — I can not find that it has ever been described in any plesiosaur. It joins the maxillæ broadly and the "supraorbital" behind; in the angle between the three bones is located the small external nares. Below the supraciliar plate, near the anterior part of the orbit, on the side of the prefrontal, there is a well-defined fossa, leading forward into the ethmoidal region, into which opens a small foramen from the upper surface between the prefrontal and supraorbital.

The *supraorbital* forms, as already stated, a horizontal plate extending out over the orbit in front. Its union with the prefrontal posteriorly is obscured by fracture, but indications of a suture are seen anteriorly. Between this bone and the postorbital there is a deep notch, angulated externally. The suture between the prefrontal and supraorbital is clearly seen anteriorly, running from the small foramen already mentioned forward and outward to terminate near the maxilla, at the posterior end of the nares. The connection of the bone with the maxilla can not be made out, as there has been an infolding here; its connecting suture with the ascending process of the maxilla is, however, well defined, running obliquely forward. The descending plate of the supraorbital has, in its orbital margin near the upper part, a small foramen, piercing the bone obliquely. The horizontal portion terminates anteriorly by sinking to the surface of the descending portion. The whole bone reminds one of the prefrontal of *Clidastes*.

The *postorbital* bone is a narrow, elongate and thin bone, united above with the postfrontal, and to a slight extent with the parietal, near the top of the epipterygoid; below to the jugal. On the right side, this bone, like the postprefrontal and jugal, has been macerated away, and, although somewhat distorted, presents no evidence of being composed of more than one element.

In the above description of these frontal elements, I have followed the usual determinations, but I am not satisfied with them. The "supraorbital," though occupying the position usual for this bone above the orbit, has relations anteriorly that are altogether unusual; the nasal and the lachrymal do not appear to exist as independent elements. It would seem more likely that this supposed "supraorbital" is really the lachrymal, if the postfrontal and prefrontal are fused into one element. Again, such a combination of the postfrontal and prefrontal and their peculiar articulations is remarkable. The very narrow frontal, while showing a distinct suture in the middle, presents no evidence of any connection with the parietal — it seems more to be a very narrow rostrum projecting in front of the parietal and separating the bones, which otherwise would answer very well for frontals. In this latter case, the so-called "supraorbital" would really be the prefrontal, and the postorbital the postfrontal or postfronto-orbital. This may seem a violent supposition, but it does not seem at all improbable to me. Nor is the union of the parietal with the premaxilla any more extraordinary than is the union of the supraoccipital with the frontal in many Cetacea.

Sclerotic plates are present in the left orbit of this specimen in a nearly undisturbed condition. There are fourteen in the ring with beveled and imbricated contiguous margins, in texture, size and position very much like the corresponding bones of the mosasaurs. The pupillary opening measures about thirty millimeters in diameter, and the entire diameter of the ring is about seventy millimeters. The occurrence of sclerotic plates in the plesiosaurs has long been known. I described them in *Cimoliasaurus snowii* in 1890, and Owen many years earlier (Fossil Reptilia of the Liassic Formation, p. 10) said: "In both orbits some of the thin sclerotic plates of the eyeball are preserved; this is the first specimen in which I have had evidence of their structure."

The *jugal* is a small element intercalated between maxilla, postorbital and squamoso-prosquamosal. The suture separating it from the maxilla runs nearly parallel with the lower border of the bone. In its posterior third this suture is very distinct; it seems to be continued forward to attain the margin of the orbit at its lower posterior part. Above, the bone is distinguished from the postorbital by a nearly parallel suture; behind by a nearly transverse suture from the squamosal. On the right side, the jugal had been separated from the other bones by maceration; its relations, therefore, are positively indicated. The bone terminates about twenty millimeters before the posterior end of the maxilla. On the inner side, just back of the rounded orbital margin, the bone articulates by a flattened surface, about the size of one's finger-nail, with the ectopterygoid. The bone is pierced on its outer surface by three or four small zygomatic foramina.

The broad, triradiate element, variously considered as being composed of, or the homologue of, the squamosal and mastoid by Owen[*], the squamosal and supratemporal by Andrews[†], the squamosal and prosquamosal by Owen and Baur, the supratemporal and supramastoid by Cope[‡], the squamosal, supratemporal and quadratojugal by Woodward[§], differs materially in its structure from that described or figured in other plesiosaurian skulls, in that the element, or elements, whatever they are, articulate proximally with the maxilla, as well as the postfrontal and jugal. Posteriorly, the suture separating the bone from the quadrate is situated as in *Cimoliasaurus snowii*, at the external angle of the quadrate, which it borders to its upper extremity. At the lower extremity there is a very distinct squamate suture, running upward and forward and becoming lost about twenty millimeters from its origin. This suture is clearly apparent on the two sides, and is also seen in the skull of *Cimoliasaurus snowii*, as it was figured by myself (l. c.) and Cope*. Just what the course of the suture is anteriorly I cannot say, but I believe that it is indicated by a line passing forward to the maxilla, and excluding that bone from union with the squamosal. Whatever be its relations anteriorly, I doubt not that the quadratojugal exists as a distinct ossification in the plesiosaurs. In a separated quadrate of another species of plesiosaur (*T. anonymum* Will.), from the Benton of Kansas, the sutural surfaces for union with the quadratojugal and squamosal are clearly distinguished. The quadratojugal does not enter into the formation of the condylar surface of the quadrate, as has been suspected, and as it does in *Sphenodon*: this is certain. On the outer side of this quadrate, just above the articular surface, there are two sutural surfaces—one on the posterior and outer border, for the attachment of the squamosal, the other on the anterior border for the attachment of the quadratojugal, which, in this case, as also in *Dolichorhynchops osborni*, must have been overlapped in part by the squamosal. In *Cimoliasaurus snowii*, the suture between the squamosal and the quadratojugal is very clearly indicated from the exterior, the squamosal not descending as low as in the other species. The suture shown as separating the quadratojugal from the squamosal anteriorly is conjectural, but I believe, as already stated, that it will be found to extend as far forward as the maxilla.

---

[*] Trans. Geol. Soc. Lond. (2), v, pt. iii, pl. xlv, 1840.

[†] Quart. Journ. Geol. Soc. Lond. lvii, 249, 1890.

[‡] Proc. Amer. Phil. Soc. xxxiii, 110, 1894. Cope, in his essay on the posterior cranial arches in the Reptilia (Trans. Amer. Phil. Soc. 1892), reaches the conclusion that the lower temporal bar of the Crocodilia, *Sphenodon*, etc., corresponds with the zygomatic arch of the mammalia, and therefore suppresses the term "squamosal." The squamosal—so-called—in the Reptilia he calls the supramastoid, absent in the lacertilia and other forms.

[§] Vert. Paleont., f. 116 A, 1898.

The suture separating the squamosal from the postorbital is short and vertical, joining the border near the anterior extremity of the bone, as seen from the outer side. The suture joining the jugal is a squamous one, extending on the inner side nearly to the margin of the orbit, but leaving a small space for the union of the ectopterygoid with the jugal. The suture with the maxilla is long and oblique, concealed in about half its extent by the jugal. I believe, however, that the squamosal is really separated from the maxilla by the intervention of the quadratojugal, as already described, and for which there seems to be some evidence in the specimen. On the right side the maxilla had been removed by maceration, leaving the sutural surface for the temporal element very clear in its whole extent.

Posteriorly, the sutural line of the squamosal passes downward by a somewhat zigzag line to reach the inner border of the quadrate a little above the border of the pterygoid process. On the inner side, the sutural line passes nearly directly across, and then upward to the inner border.

---

* Proc. Amer. Phil. Soc. 1894.

The connection with the parietal is definite. The suture indicated by Cope in his figure of *Cimoliasaurus snowii* (l. c.) does not exist in the specimen figured, nor is there any such in the skull of *Dolichorhynchops osborni* here described. In order to definitely determine this fact I removed the portion supposed by Cope to be the supramastoid from the skull of the *Cimoliasaurus* specimen and carefully cleaned it, thereby proving beyond peradventure that the supposed suture is in reality a fracture. The squamosal, or as it should be called, the squamoso-prosquamosal, in that form, as will be described hereinafter, reaches to the top of the skull, notwithstanding Baur's opinion to the contrary. The two squamosals touch each other, or nearly do so, as in the skull of *Cryptoclidus* described by Andrews.

The temporal bar in the plesiosaurs, it is thus seen, is composed of the jugal, quadratojugal, squamosal and prosquamosal (supratemporal). This last element is not distinct in either of the skulls here described, nor is it usually apparent in the adult skull, but Owen[*] describes and figures it as distinct; Andrews also says[†] that "In several Plesiosaurian skulls in the British Museum the suture between these elements is distinct."

The *quadrate* is a short and broad bone, united by a pit-like sutural surface on the inner side with the posterior prolongation of the pterygoid, on the outer side with the squamosal and quadratojugal, as already described. Posteriorly the sutural surface for the squamosal begins a little above the pterygoid articulation, runs downward and outward for a short distance, then upward and outward to another point, whence it goes downward to appear on the outer surface a little below the angle of the bone, which it follows nearly to the lower articulation. The articulation for the paroccipital is immediately above and before the pit for the articulation of the pterygoid. A separated quadrate of another species (*T. anonymum*), already described in part, with its sutures distinct and the bone undistorted, shows an elongated articular surface, broadest upon the inner end, narrowed and turned upward at the outer extremity nearly to the lower end of the squamosal articulation. A non-articular groove on the inner side of the middle behind divides the articular surface; it does not appear to be present in either of the other species. The pterygoid articular surface reaches to within about twenty-five millimeters of the articular extremity. The inner border of the pit is produced forward for articulation, apparently, with the paroccipital. The two narrow, concave, articular surfaces for the squamosal and quadratojugal are separated by a narrow, non-articular ridge. They both extend very nearly to the cotylar surface of the bone.

---

[*] Trans. Geol. Soc. (2). v. Pl. xiv (1840).

[†] Quart. Journ. Geol. Soc. lii. 250. 1896.

The *pterygoids* articulate posteriorly by a deep, pit-like suture with the inner side of the distal extremity of the quadrate; the latter does not send out a process to meet the bone. The bar connecting the quadrate with the body of the bone is oval in cross-section, with a rounded inferior border. It is about thirty millimeters in length and is placed obliquely; it does not extend much posteriorly to the coronal plane of the occipital condyle. In front of this quadrate process there is an elongate, flattened or concave plate, with nearly parallel sides, separated from the parasphenoid by a slender, elongated vacuity.* At the posterior extremity of this plate there is a narrow bridge connection with the basisphenoid. The connecting suture is not determinable, so that one cannot say whether the two pterygoids meet here in the middle, as in *Peloneustes* and *Pliosaurus*, or are separated, as in *Plesiosaurus*. In front of the interpterygoid vacuity the pterygoids unite with the parasphenoid broadly; here also the connecting suture cannot be determined. Opposite this connection exteriorly, the bone sends out a stout process for union with the ectopterygoid or transverse bone. Back of both of these, and on the inner side, near the margin of the vacuities above, there is the attachment of a stout *epipterygoid* pillar, passing upward, and apparently a little inward to unite with the lower anterior part of the parietals, as already described: both extremities are tumid, and the connecting sutures cannot be determined. The rod is broken on both sides in the specimen near the parietal end, and, as preserved, is curved forward. It is oval in cross-section, with the greater diameter of about ten millimeters; the entire length is thirty millimeters. Anteriorly, the pterygoid sends a flattened process to meet the posterior extremity of the vomers; it is flattened and pointed. This process is gently expanded at each extremity, especially the proximal; it has a smooth, thin edge on each side, except at the distal end, where it meets its mate, suturally, in the middle. Between the two processes there is an elongate, oval vacuity, which is not filled by the ossified parasphenoid in this specimen. There is, however, a slight projection in the middle of the opening behind, which may represent a more extensive ossification, but it seems very probable that there was a real vacuity here, unlike the condition in *Peloneustes* and *Plesiosaurus*. The union with the vomer is oblique, from without inward and forward.

---

* Andrews calls this opening the posterior palatine vacuity or foramen; but this term is more properly restricted to the opening between the palatine, pterygoids and maxillæ, corresponding to the posterior palatine foramina of mammals, and is thus used in the Chelonia—the sub- or infra-orbital vacuity of Andrews and other authors.

The *palatine* and ectopterygoid on one side, though retaining their original positions approximately, were free in the specimen; they are complete and show their sutural relations very well. On the other side, they are both in position. The palatine is a long, narrow, thin bone, concave from side to side above, and correspondingly convex below. The inner, slightly sinuous margin is thin, and overlaps the outer margin of the palatine process of the pterygoid. Near its anterior extremity there is a small emargination for the nares*, where

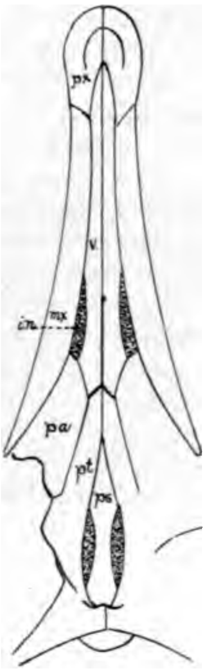


FIG. 1.

Palate of *Peloneustes*.

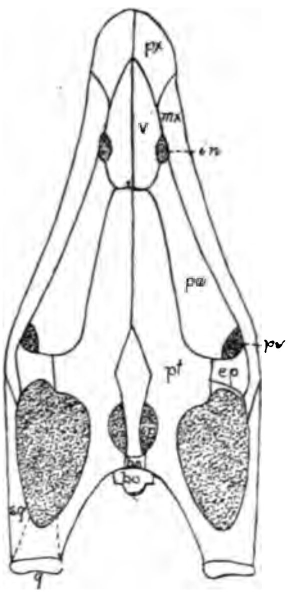


FIG. 2.

Palate of *Plesiosaurus*.

Px., premaxilla; *mx.*, maxilia; *v.*, vomer; *in.*, internal nares; *pa.*, palatine; *pt.*, pterygoid; *pv.*, posterior palatine vacuity; *ep.*, ectopterygoid; *bs.*, basisphenoid; *bo.*, basioccipital; *q.*, quadrate; *sq.*, squamosal. After Andrews.

---

*See description of the palate in *Brachauchenius* beyond.

the bone comes in contact with the proximal end of the vomer; for a little distance in front of this emargination, and distad to the pointed extremity of the bone, the border is slightly thickened for union with the vomer. Posteriorly, the rounded extremity of the bone is slightly thickened, and with sutural roughening for union with the ectopterygoid process of the pterygoid. The outer border is slightly concave throughout nearly its whole extent; it is also thin for nearly its whole extent. Anterior to the small narial emargination, the bone forms a long, slender point. On the proximal end, the thin border is underlapped by the thin anterior prolongation of the ectopterygoid for a distance of about fifty millimeters; the remainder of the extent comes in contact with the maxilla, but presents no distinct sutural surface, unless it be near the anterior extremity. There is no posterior palatine foramen.

The *ectopterygoid* or *transverse* bone is of a slender, triangular shape. Its slender anterior end extends forward on the outer margin of the palatine. The posterior inner angle has a well marked sutural surface underlapping the pterygoid process. The outer extremity is thickened, curving somewhat downward to unite with the jugal, and, by a thin border, with the maxilla.

The *vomer* is a very long, narrow bone, uniting with the palatine process of the pterygoids posteriorly by a squamous suture, and, for a short distance on the outer side posteriorly, with the slender pointed extremity of the palatine, the small narial opening intervening. They lie closely side by side, apparently without sutural union. They are concave above, and convex below from side to side, and are rather stout. The anterior ends are so concealed that they can not be described or figured.

BRAIN-CASE.—The lateral walls of the brain-case in the reptilian skull are composed of six distinct elements, according to the views of some comparative anatomists. Two of these may be fused with contiguous elements in the adult skull, or one or more of them may be entirely absent. Those elements supposed to contain the otic capsule were called by Huxley, in his lectures on the structure of the vertebrate skull (Elements of Comparative Anatomy, 1864), the epiotic, prootic and opisthotic. The other three are the supraoccipital, exoccipital and alisphenoid. The epiotic, Huxley homologized with the so-called epiotic of fishes and batrachians, and, although indistinguishably united with the supraoccipital in all adult reptilian skulls*, he believed to be a distinct ossificatory element. This has been denied by Baur*. No indications of such an ossification have been found in adult reptiles, living or extinct, even in those in which the opisthotic remains as a permanently free ossification. The opisthotic was previously called paroccipital by Owen in 1838, and the name must take precedence. Cope†, however, suspected that the opisthotic or paroccipital is really composed of two elements, the outer of which is the true paroccipital, while the inner, that entering into the formation of the otic canals, may be properly called the opisthotic. Baur denies this, insisting that there is but a single element, persistent in the Testudinata, Ichthyopterygia, the young of *Sphenodon*, and other Rhynchocephalia, as well as in some of the Cotylosauria; firmly and indistinguishably fused with the exoccipital in all other reptiles, so far as is known: free, according to Cope, also, as the so-called squamosal of Baur, the paroccipital of Cope, the supratemporal of Woodward‡, in the lacertilia.

---

* Parker describes the epiotic as a distinct element in *Tropidonotus natrix*. Phil. Trans., 1878, p. 405.

If there be but one element here, and, so far, the evidence is inconclusive that there are two, then it must be called the paroccipital, a name first given to it by Owen. Andrews describes the element as distinct in the young of *Cryptoclidus*§, but there are no indications of it in the present specimen.

The proötic of Huxley, the alisphenoïd of Owen (Comparative

---

*Zool. Anzeiger, No. 296. 1889: Journ. Morphology. 1889. p. 467.

† "The opisthotic in reptiles is generally early fused with the exoccipital, but in the Ichthyopterygia and Testudinata it is distinct, and takes the place of the petrosal as a support for the quadrate in conjunction with the exoccipital. In the Pythonomorpha a bone which occupies the position of the terminal part of the opisthotic (or paroccipital, which is the older name) issues from between the exoccipital and petrosal, and supports the quadrate. Whether this is homologous with part or all of the paroccipital is an open question. For the present I call it the paroccipital and it is probably a distinct element from the opisthotic." Cope, Syllabus, 2d ed., 1898. A fuller description of the relations of this bone the reader may find in my paper on the Mosasaurs (Univ. Kansas Geol. Surv., vol. iv, p. 121). After much reflection I believe that Cope is right in rejecting the term squamosal for this element, whatever it is. Parker describes and figures the opisthotic as a large element in the snake (l. c.), occupying its usual and normal position. At the same time it is exceedingly difficult to believe that the remarkable relations of the bone in the mosasaurs can be those of the squamosal, occupying almost the normal position of the real opisthotic. That the bone called the prosquamosal in the lizards is not the squamosal would also seem probable, though not impossible. I prefer to call the elements, until it be proven that there are two opisthotics in the lizard, the paroccipital and prosquamosal with Cope. It is of interest to note, however, that Cope, in his last edition of the Syllabus (published posthumously), retains the name of squamosal for the element he previously called the supratemporal (*i. e.*, the prosquamosal). Further on he defines the plesiosaurs as follows: "No supramastoid; paroccipital not distinct; a quadrato jugal arch; scapula triradiate; no clavicle; ribs one-headed." Cope's supramastoid is the bone he thought erroneously to exist in the skull of *Cimoliasaurus snowii*, that is the real squamosal if present, and Andrews assures us that it is sometimes present in the young animal. I do not understand what is meant by "no clavicle," unless it be that he accepted Hulke's determination of these elements as the omosternum, a subject which will be discussed further on. He forgets also that some plesiosaurs do have rudimentary double-headed ribs in the cervical region.

Notwithstanding all that has been written, the homologies of the temporal bars in the reptilia are yet uncertain, more so than any other parts of the reptilian skull.

‡ Vertebrate Paleontology, 1898.

§ Geological Magazine, 1895, p. 242.

Anatomy), is the petrosal of earlier authors, about which there is now no discussion. It always articulates behind with the exoccipital and paroccipital, above with the supraoccipital, below with the basisphenoid, and to a greater or less extent with the parietal (in certain lizards, etc.), the alisphenoids, when present, and epipterygoids. The epipterygoid, the columella of earlier authors, unites the pterygoids with the parietals or frontals. It has been supposed to be identical with the alisphenoids by Baur and others, but Baur[*] later retracted this opinion, with reason, as may be seen by an inspection of the cranial walls of *Sphenodon*.

The alisphenoids (orbitosphenoids of Owen) articulate with the basisphenoid below, when present, and with the petrosals behind. In the crocodilia and *Sphenodon* they also articulate with the epipterygoids. They seem to be absent in the plesiosaurs.

The bones of the brain capsule in our specimen of *Dolichorhynchops* had been separated by maceration before fossilization, and were more or less displaced and entangled with one another. Moreover, in each temporal vacuity there had lodged deeply a thoracic vertebra, wedged in and causing more or less distortion of the temporal arches. The atlas and axis, also, were crowded into the occipital region. The vertebræ had to be sacrificed in order not to endanger the other bones. Mr. Martin, with great care and patience, removed the disassociated bones of the capsule in more or less completeness. They were all soft and mealy, almost of the consistency of brown sugar when wetted, but by carefully infiltrating them with a solution of gum arabic, the bones were hardened bit by bit and then removed from the matrix. This exposed the surface of the basioccipital and basisphenoid in their entirety, in an undisturbed and uninjured condition. A gelatine mould of this surface was then made, from which a plaster cast was taken, showing the sutural surfaces for the exoccipitals and petrosals. While none of the bones were obtained quite complete, yet the mates, for the most part, mutually indicate the complete characters of each, thus enabling a nearly complete restoration of the capsule to be made. And the results have been well worth all the trouble, as the bones present certain features of much interest.

The brain cavity is broadly open in front, as in the lizards[†] and *Sphenodon*, with a broad base on the basisphenoid, a deep depression for the pituitary, a narrow roof under the parietal, an open vacuity posteriorly in the supraoccipitals, and with a relatively large otic capsule. The *exoccipitals* unite obliquely with the basioccipital, taking no part in the formation of the condyle. The paroccipital processes are small and slender, and there is no indication of a distinct ossification. They are dilated slightly at the extremity, where they abut against the upper part of the quadrate. They are directed downward and outward, the distal extremity reaching a level below the top of the occipital condyle. The occipital foramen is transversely oval, if the upper end is assumed to be near the top of the exoccipitals, which show a slight angularity at the place of their union with the separated supraoccipitals. At the upper posterior extremity of each exoccipital there is a small, deeply excavated, angular cavity, excavated almost wholly from the exoccipital, its upper border only touching the posterior angle of the supraoccipital. Its excavated surface is smooth and sharply angular, looking upward and inward. This surface probably corresponds to the smooth tendinous surface seen on the outer angle of the supraoccipital, extending slightly on the corresponding angle of the exoccipital, in the crocodile. At the posterior part, the exoccipitals approach each other rather closely, leaving about four millimeters of basioccipital space in the circumference of the foramen magnum. Anteriorly, however, the two bones diverge rather widely, terminating a little posterior to the suture separating the basioccipital from the basisphenoid. On the inner side, back of the middle of the bone, and a third of the distance above the sutural margin, is the large oval foramen for the vagus, opening exteriorly below the middle of the moderately expanded paroccipital process. The smaller foramen for the hypoglossal is situated midway between this and the posterior margin, and nearer to the sutural surface; it opens near the vagal orifice. The sutural surface for the supraoccipital is flat and broadly triangular, pierced near its middle by a small foramen leading into the posterior semicircular canal in the supraoccipital, the floor of which is seen on this surface, leading

---

[*] Zool. Anzeiger. No. 298. 1889.

[†] In the Pythonomorpha I have recently discovered that the brain-case is bounded in front in part by a well developed orbitosphenoid, uniting the frontal with the basisphenoid. The same bone is present in the lizards and snakes. See Bulletin Kans. Univ., 1, No. 9. p. 14.

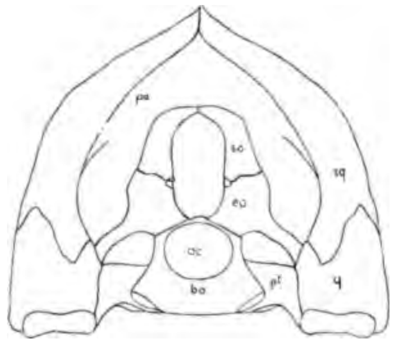


FIG. 3.

Dolichorhynchops osborni. Occipital view of skull. × ⅓. *Pa.*, parietal; *sq.*, squamosal; *q.*, quadrate; *so.*, supraoccipital; *eo.*, exoccipital; *pt.*, pterygoid; *oc.*, occipital condyle; *bo.*, basioccipital.

as a narrow groove to the inner posterior margin of the surface. Posteriorly the slit for the eighth nerve seems to be a little above and back of the vagal opening, in the interstice between the exoccipital and petrosal. The large cavity of this bone looks backward to communicate broadly with a similar cavity in the petrosal on the inner side. On the outer side there is a small foramen, nearly or quite separated from the inner opening, also communicating with a small foramen in the opposed sutural surface of the petrosal. Externally the exoparoccipital shows a narrow fossa below the process, into which open the vagal and hypoglossal foramina. Above, the gently convex surface continues into the similar surface on the sides of the supraoccipitals. The posterior borders of the exoccipital and supraoccipital meet in an obtuse angle, which is excavated, as already described for ligamentous attachment.

The *supraoccipitals* are not only parial, but they are widely separated from each other, approaching each other only at the upper extremity posteriorly. They enclose between their smooth, narrow edges posteriorly a large vacuity, continuing the foramen magnum quite to the parietal roof. This relation of these bones I can not find paralleled in any reptiles. Though paired in the Stegocephalia, as also in *Pariotichus*, they meet in a median suture. Whether this peculiar structure obtains in all other plesiosaurs I can not say, inasmuch as the only references to the supraoccipitals which I find in the literature is a brief one by Andrews* concerning the bone in the young of *Cryptoclidus*, in which nothing is said of a similar structure, and a notice by Owen†, who describes the supraoccipital in *Plesiosaurus dolichodeirus* as a single, arched bone.

The inferior articular surface for union with the exoccipital is flat and triangular in shape, looking downward or slightly backward. It is pierced near its middle by the foramen for the superior semicircular canal. The sutural surface for union with the petrosal meets the exoccipital at an angle of about one hundred degrees, and is flattened or gently concave, and shorter than the other sutural surface. The external surface is moderately convex, and a little roughened. The posterior border is thin and smooth, deeply concave and sinuous, the upper extremity curved inward. The inner surface is quite smooth, gently convex from before backward, nearly straight to its upper third, where it bends strongly inward. The posterior border is short, thick, convex from side to side, and concave on its upper part before joining the sutural surface. The sutural surface above, for union with the parietal, is elongate oval in shape, slightly convex in both directions, and turned obliquely inward posteriorly, so that the two bones when in place form a V. The surface looks forward and upward, and joins a projecting sutural surface of like shape on the parietal bone.

---

*Geol. Mag. 1895, p. 242.

†Fossil Rept. Liassic Formation, p. 8.

MANDIBLE.—From the exterior of the mandible four elements are visible, arranged much as in the crocodile or *Sphenodon*. The dentary extends far back along the upper border, quite to the top of the coronary eminence. Thence its suture runs obliquely to a little beyond the posterior end of the symphysis on the lower border. The element back of this on the upper border is doubtless the surangular, separated from the angular below by a suture placed very much as it is in the crocodile, beginning at the extreme posterior end of the mandible. The bone extends anteriorly as an elongated point between the dentary above and the angular below. The suture separating the element from the articular cannot be made out. The two, united, agree quite with the element described by Guenther in *Sphenodon*, and as seen in a specimen fifty-eight millimeters in length before me. I distinguish in this mandible, as did Guenther in his, only four elements —the dentary, which reaches far back; the coronoid, a flat triangular bone occupying its usual place; the articular, inclusive of the surangular; and the angular. Baur* describes five elements in a *Sphenodon* skull fifty-six millimeters in length. The articular he restricts to a small nodule or disk of bone, similar to that of the turtles, forming the articular surface; the surangular, the bone before the cotylus, which he indicates as separated by a suture; the angular he considers to be the inner prolongation of the bone which reaches to the coronoid. The slender bone usually called the angular he believes to be the splenial; while the bone usually called the splenial (presplenial, Baur) in the crocodile and lizard he believes to be wanting in the *Sphenodon*, as it usually is in the turtles. The small ossification which he finds in the cotylus of the young *Sphenodon*, similar to the element in a like place in the *Testudinata*, he assumes to be present in all reptilian mandibles, but is obliterated in the adult skull by the anchylosis of the suture. I certainly do not find such a bone in the *Sphenodon* mandible before me, nor could Guenther distinguish such an element. He believes then, that the element usually considered the articular, is in reality composed of two bones — a chondrogenous articular part and a dermogenous anterior prolongation. This is probably true, but I do not see the necessity of changing the names of the other anterior elements and of calling this anterior prolongation the angular, as does Baur. From the fact that the bone on the inner side of the dentary, covering Meckel's groove, is the only one which can with propriety be called "splenial" (a "bandage" or "patch"), or opercular (a cover), it will be better to retain the former name for the element, as usually applied, and to give a new name to the part separated from the articular, wherever it exists as an independent bone; it may be called the *prearticular*.

---

* American Naturalist, 1891.

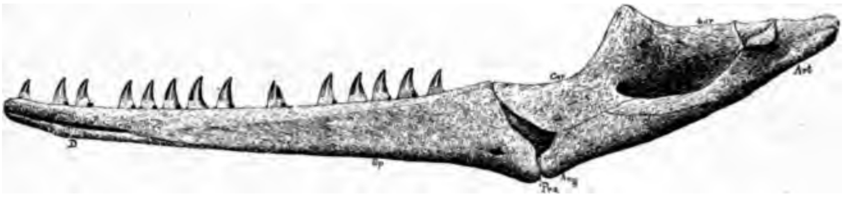


FIG. 4.

Right mandible of *Clidastes tortor* Cope. *D.*, dentary; *sp.*, splenial; *pra.*, prearticular; *ang.*, angular; *cor.*, coronary; *art.*, articular; *sur.*, surangular.

I assume that the element containing the cotylus must be the *articular*, and that the one in front of it, back of the coronoid and dentary, must be the surangular, though, as already stated, I can find no positive evidence of a separating suture in the present specimen, as is also the case in the adult *Sphenodon* mandible. Doubtless in some more fortunately preserved specimen, or in one of a younger animal, the separating suture will be traced. I will add that the suture indicated by Cope* in his figure of the skull of *Cimoliasaurus snowii*, as separating the articular from the surangular, does not exist in the specimen; the place is indicated by a mere groove only.

The *angular* is very long, and is extensively visible from both within and without. On the outer side it is seen reaching to a little beyond the proximal end of the symphysis, where the pointed extremity is visibly intercalated between the dentary and a small portion of the splenial. On the inner side, the suture follows inward below the cotylus to the anterior inner angle of the articulation, near which it passes upward to meet the prearticular. The bone passes beneath this latter element but its connection with the surangular cannot be made out. Along the inferior border of Meckel's groove and the splenial, the suture goes forward to near the proximal end of the symphysis.

On the inner side of the mandible, there is an extraordinary arrangement of the bones. After much deliberation, I interpret them as the splenial (presplenial of Baur), the prearticular (angular of Baur), and the coronoid. The identity of the *splenial* is assured. It has been dislodged upward slightly, disclosing the narrow Meckelian groove, which terminates in an orifice at the proximal end of the splenial. The bone ends posteriorly below the coronoid eminence. Anteriorly it broadens so as to cover all but the upper inner part of this surface, uniting with its mate to form the symphysis. From below, the thickened bone forms the inner part of the symphysis for a short distance forward, at least. How far it extends can not be determined, as it gradually becomes thinner and disappears from view. (See Pl. II.)

---

*Proc. Amer. Phil Soc. 1894.

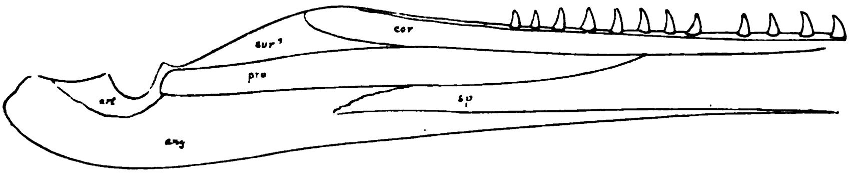


FIG. 5.

Left mandible to symphysis of *Dolichorhynchops osborni*. *art.*, articular; *pra.*, prearticular; *sur.*, surangular; *cor.*, coronary; *sp.*, splenial. Compare also Pl. II.

The bone which I determine as the *coronoid* is most peculiar, remarkably unlike that in any other animal which I know. It is a long, slender, flattened, trihedral bone, extending far forward, and like the splenial, meeting its mate in the median symphysis. It extends as far back as the end of the dentary, along its inner side, to the most elevated part of the surangular, where it is thin and spatulate. It follows the inner margin of the dental border of the dentary, apparently at least as far as the middle of the symphysis. At the beginning of the symphysis with its mate, the bone is somewhat triangular in cross-section, with its thin margin below touching the splenial: the mesial surface is in contact with that of its mate, while the upper surface is narrow. On one side the bone, while still retaining its proper relation with that of the opposite side, has been partially dislocated from the mandible, so that there can be no question of its morphological relations to the contiguous elements.*

Between the splenial and the coronoid, on the inner side, is seen a narrow, thin bone, corresponding quite to the dermogenous portion of the articular in the turtles and Rhynchocephalians, that is, the angular of Baur. It lies above the splenial, disappearing beneath the coronoid anteriorly. Posteriorly it is joined by a suture with the articular, approaching but not quite entering into the cotylar surface, or if so, only to a slight extent. This end has been dislodged slightly from its normal position and is slightly twisted upward. It is scarcely possible that this is due to fracture, since the surface has all the indications of a suture, and a fracture could hardly have occurred here without injury to the bone underneath. The end is slightly thickened and fits into a pit on the anterior upper part of the articular rim; just below the suture, separating it from the articular, there is a longitudinal ridge-like roughening, and a narrow, deep pit. This element I call the *prearticular*.

---

*This peculiar relation of the coronoid is well illustrated in fig. 13, p. 476, vol. xxxvii, of the Quarterly Journal of the Geological Society, in Prof. Sollas' article on "A New Species of Plesiosaurus from the Lower Lias of Charmouth."

For the sake of comparison, I have figured in Pl. V the mandible of *Sphenodon*, *Crocodilus*, *Chelydra*, *Varanus*, with the interpretation of the elements as here accepted.

The bones of the skull, as of the entire skeleton, seem to have had a sort of postmortem plasticity. Apparently during life the sutures everywhere were free, and the parts all readily separable, and wherever the bones have been disturbed or distorted the sutures have pulled apart and widened. Where there has not been such disturbance, however, the sutures are often obliterated, the elements fusing together. This would seem to indicate youth, but plasticity in the Cretaceous skeletons was largely due to the composition of the bones, which may have been more or less persistent throughout life. Those in which the inorganic proportions were large have suffered less from postmortem disturbances than those in which the organic material was considerable. Bird bones were never plastic, and very rarely are the bones crushed, the cavities being filled with crystalline material often. Of the pterodactyls, however, the bones are invariably found crushed, though presenting little evidence of plasticity. Among the mosasaurs, the more firmly ossified bones of *Clidastes* are less often changed in shape, while the Tylosaurs, on the other hand, were more or less subjected to a plastic distortion. The structure of the plesiosaur bones in all that I have seen is unusually soft.

VERTEBRÆ.—*Atlas* and *axis*. (Pl. XXII.) The *atlas* has the usual number of elements, the intercentrum and the two side pieces, or neurapophyses. It will be convenient, however, to describe in this connection the parts of the whole axial and atlantal complex, that is, in addition to the odontoid, the axial intercentrum and the axial centrum and arch. The arrangement of all these parts is very like that in the lizards, crocodiles and various other reptiles, save that the structure is somewhat more primitive or generalized. The atlantal intercentrum is the largest element of the complex, save the axial centrum. It has five articular surfaces for union with as many bones; four of these surfaces are sutural, and, doubtless in old animals or in other species, the sutures may be obliterated. The inferior or ventral surface has an obtuse ridge along the middle, on either side of which the surface is flattened or a trifle convex. This surface is free, and its anterior and posterior margins are parallel. The anterior or cephalic surface is concave for articulation with the hemispherical occipital condyle, its rim forming more than one-third of the entire circumference of the cup. The posterior surface is flat, elongated triangular in shape, with a V-shaped emargination, for articulation with the axial intercentrum. Dorsally the bone articulates by a broad sutural surface with the odontoid, except on the cephalic part of each lateral margin, which unites by a small, semi-oval surface with the neurapophysis.

The axial intercentrum is not unlike the atlantal in shape, when seen from the ventral side, though smaller. Its ventral surface continues the obtuse ridge of that intercentrum, but it is here quite prominent, the nearly square free surface on either side being distinctly concave. The posterior surface for sutural union with the body of the axis is flat or gently concave; its free margin is broadly V-shaped, with the inferior angle rounded: the dorsal margin is gently concave in the middle to the truncated, very broad arms of the V. The cephalic sutural surface is flat, for union with the atlantal intercentrum, and like that of this bone, its surface is broadly triangular in shape. On either side the bone articulates, through the greater part of its extent, by an oblique, concave surface with the axial rib, forming part of the pit for the reception of that bone. Its upper lateral part unites by a small surface with the odontoid, forming with it and with the axis the complete margin of the rib-pit. Dorsally the bone articulates on its caudal half with the axis: on its cephalic half with the odontoid.

The odontoid, or atlantal centrum, unites posteriorly by a broad, flattened, sutural surface with the body of the axis. On the cephalic side there is a concave surface in the middle, occupying about one-half of the diameter for articulation with the condyle, the deep cup being completed ventrally by the atlantal intercentrum and on the sides by the neurapophyses. Dorsally the neurapophyses leave a small notch of the rim incomplete, which is partly filled out by the odontoid, making the diameter of the cupped surface of this bone greater dorso-ventrally than from side to side. The sides of the bone have a free, irregularly trapezoidal surface, the longer, cephalic border articulating with the atlantal neurapophysis, the caudal, oblique border with the axial intercentrum, the ventrocaudal angle with the axial intercentrum, and the ventral part of the caudal border with the axial rib, its dorsal angle touching the axial neurapophysis. The ventral side of the body unites suturally with the intercentra. On the dorsal surface there is a narrow, free space, which helps form the floor of the neural canal.

The *lateral pieces* or *neurapophyses* are composed of a large body for sutural union with the other elements, and a small, laminar, dorsal projection, which is free. The body is irregularly five-sided, the external free surface convex dorso-ventrally. The cephalic surface is smooth and concave, forming the lateral rim of the condylar cavity. Ventrally a small articular surface is for union with the condylar rim of the atlantal intercentrum; the border nearly parallel with the upper. Caudad, there is a small articular surface for union with the arch of the axis; the long border between these two joins the lateral surface of the odontoid; the dorsal surface sends a flat projection backward to touch, or nearly touch the small, vestigial prezygapophysis of the axis; this lamina is continued into a small, flat process, the vestige of the neural lamina. These neurapophyses are peculiar in articulating at their base for a short distance with the neurapophyses of the axis, doubtlessly corresponding to the articular surfaces between the body of the axis and the lateral masses of the atlas in the mammalian vertebræ. It is very plainly evident, therefore, that the name zygapophysis, when applied to this articulation in the mammalian axis and atlas is incorrect—the real zygapophyses are completely lost.

The atlas, as a whole, is of a primitive and generalized character, in that the neurapophyses are, for the most part, borne by their own centrum, and the atlantal arch only in small part by the atlantal intercentrum.

The *axis* has its anterior surface flattened for sutural union with the odontoid. On the cephalic ventral part is received the axial intercentrum, the lines of the union reaching midway of the body on the ventral side. The pit for the reception of the rib is very large and deep, and is formed in part by the odontoid and intercentrum. The pedicles of the arch are stouter and broader than in the following vertebræ, articulating in front with the lateral pieces of the atlas, and, to a slight extent, with the odontoid. The prezygapophyses are represented by a small tubercle, approximated to the flattened posterior process of the lateral atlantal pieces. Back of this there is a thickened, rugose, horizontal ridge, reaching to the intervertebral notch. The posterior zygapophyses are situated rather high, and do not differ materially from the same processes in the following vertebræ. The spine is incomplete posteriorly, but seems to have been short, stout and much inclined.

The structure of the plesiosaurian atlas and axis has been described by Owen,[*] Huxley[†] and Barratt.[‡] In the specimen of a *Plesiosaurus* described by Barratt the different elements were separated and were for the most part complete. The neurapophyses differ markedly in their expansion inward to form a roof for the neural canal, though they do not touch each other. The atlantal intercentrum also differs in its posterior projection into "two long processes," which are, however, broken away, leaving only their bases. The axial rib seems, to articulate with the axis and axial intercentrum only. In *Plesiosaurus etheridgii*, the atlas and axis of which are described by Huxley, the bases of the atlantal neurapophyses are much larger and meet above the odontoid. In *Plesiosaurus pachyomus*, as described by Owen, "the anchylosed bases of the neurapophyses form the upper border of the cup," and the atlantal intercentrum "develops a thick but short rough tuberosity from its under part," and the rib projects from the centrum of the axis only. The processes were all broken away.

It is seen that the structure in *Dolichorhynchops* is more specialized than in these species of *Plesiosaurus*.

The atlantal and axial intercentra, variously considered by different authors as "subvertebral wedge-bones," hypapophyses or hypocentra, are correctly homologized by Baur,[§] Albrecht[||] and Osborn.[¶] It is a little interesting to note, however, that Owen (l. c.) long ago gave a correct hint of their homology: "According to the latter view, what has usually been regarded as the centrum or body of the atlas in Saurians, Chelonians and the higher Vertebrata, would be the hæmapophyses of that vertebra; and the odontoid process the true centrum." He concludes, however, that these elements are "detached cortical parts of the real centrum;" though later he correctly compares them with the hypocentra of the labyrinthodonts.

Perhaps the most primitive and unchanged condition of these elements in the reptilia is found in *Ichthyosaurus*, in which, as shown in the figures given of the axis and atlas by Owen, the intercentra of the first three vertebræ occupy nearly their normal and unaltered relations to the vertebræ. It is difficult to understand, however, how such a primitive condition of these parts could have been inherited from a terrestrial ancestor. In the plesiosaurs the specialization has been carried further, still the structure is yet more primitive than is known in any modern reptiles and in most of the extinct. We certainly can look for ancestral forms of these vertebræ among the Stegocephalia or Anomodonts only; in all other reptilia they have acquired too great specialization to easily revert to the generalized structure.

---

[*] Ann. Mag. Nat. Hist. xx, 217, 1850.

[†] Geological Journal, 1858.

[‡] Ann. Mag. Nat. Hist. Nov. 1858.

[§] American Naturalist, 1887, Sept., p. 839.

[||] Bull. Mus. Roy. d'hist. Nat. de Belg. ii, 185.

[¶] Mem. Amer. Mus. Nat. Hist. i, p. 167.

In the modern crocodiles the specialization has been carried so far that the axial rib has become supported by the atlantal centrum only, while the atlantal rib has been pushed forward on the atlantal intercentrum.

It is of interest to observe that in *Shastosaurus* of the earlier Ichthyopterygia, according to Merriam, there were probably five intercentra present in the anterior cervical region, while in *Ichthyosaurus* there are but three, and in the more specialized forms, *Baptanodon*,* they have entirely disappeared.

Beyond the axis there are seventeen distinctly *cervical vertebræ* preserved, together with one or two transitional ones, which must be classed with the dorsals, however. I believe that these were all that the animal possessed, though it is possible there may have been one or two more. The arches and ribs of all, save of the third, were detached and scattered about among the other bones, so that much difficulty was encountered in properly associating the parts. Because of a gradual increase in size of the ribs and arches, as well as the centra, it would seem that the final collocation made is correct, and because all these processes agree in number it would seem still more probable that no vertebræ are missing. (See Pls. VI–IX.)

The centra increase in height and width gradually throughout the series. The third has a transverse diameter of thirty-five millimeters, a height of thirty and length of twenty-eight. The sixteenth centrum has its corresponding diameters as follows: forty-five, thirty-eight and twenty-six. The three following are somewhat distorted, but seem likewise to increase slightly in height and width. It will be observed that the length is nearly or quite the same in all, the differences being exhibited in the width and height only. The articular surfaces of the centra are gently and evenly concave, with a slight rounded eminence

---

*W. C. Knight, *in litt.*

in the middle of the concavity, sometimes apparently obsolete. The margins are rounded, the cartilaginous borders limited exteriorly by a slender, smooth line. On the ventral surface, near the middle antero-posteriorly, there are two vascular foramina, at the bottom of a slight depression, and separated from each other by a rounded ridge. Posteriorly the distance between these foramina becomes greater. The pit for the articulation of the cervical rib occupies nearly the whole length of the centrum, between the cartilaginous margins, and reaches also nearly to the plane of the neural surface. The ribs increase in length and width from the axis to the beginning of the thorax. They are single headed, flattened, with the free extremity moderately dilated and thinned, except those of the axis, which are more styliform, and are directed more obliquely backward. On the following vertebræ they are directed outward and backward, with the distal extremity rounded, except in those of the anterior vertebræ, where the anterior part distally is slightly angulated, as though suggesting a rudimentary anterior projection. The spines slope gently backward. They increase but little in length, that of the third vertebra measuring forty-eight millimeters in length while that of the last is but fifty-five above the zygapophyses. They increase in stoutness, however, much more than in length, the anterior ones being slender, the posterior broad and thick with a somewhat expanded cartilaginous extremity. The zygapophyses are broadly separated throughout, with an obliquity of about thirty degrees from the dorsoventral plane. They are broadly oval in outline, of large size and nearly flat. They project strongly from the body of the vertebra, leaving a space of about ten millimeters in extent between the centra, when in close articulation, for the intervening cartilage. The diameter of the spinal canal throughout the series is about fifteen millimeters. Upon the floor of the canal there are two venous foramina, near the middle.

Thirty *dorsal* vertebræ were found in the matrix. The arches were invariably separated from the centra, and, because of the general resemblance of the latter it is impossible to say whether all have been correctly associated. The centra were in large part crushed or compressed, and in some cases were so soft that it was found impossible to remove them entire. Two of the arches were wedged into the temporal fossæ of the skull in such a way that it was found necessary to largely destroy them in cleaning the skull. In general, the spines of the dorsal region were so soft and frail, intermingled as they were, that they could not be removed. A large part of them, hence, have been modeled in the restored skeleton. Because, however, of not a few arches that were recovered complete, or nearly so, from different parts of the series, the restoration of the intervening parts of the series has presented few difficulties.

The spines decrease very slightly in height, in breadth and in thickness. Anteriorly they are directed somewhat backward, but soon become quite vertical in position. In the posterior cervical and anterior dorsal region the spines present a much larger, oval and truncate extremity for ligament or cartilage; this surface measures from twelve to fifteen millimeters in width in some of the posterior cervicals. In the posterior dorsals the extremity is narrow—three or four millimeters in width. The first diapophysis* is small, for the attachment of a small, short rib, and is situated low down on the pedicle,† close to the sutural surface. The next is much stouter and longer, for the attachment of a long and strong rib. The next two or three ascend progressively on the pedicle, until in the fifth the upper margin of the root is above the plane of the anterior zygapophyses. They retain this position throughout the series, the last two or three, only, descending toward the centrum. The diapophyses have acquired their greatest length by the sixth or seventh, and are directed upward and outward. In the articulated skeleton there is a deep costo-spinal groove on either side. The zygapophyses are largest and stoutest in the posterior cervical region, decreasing gradually in size, and becoming obsolete at the base of the tail. Throughout the dorsal region they are but slightly cupped, and are directed dorsad and ventrad, at only a slight angle from the median plane. There are no indications whatever in any region of a zygosphene. The centra throughout this region were more or less crushed in the specimen, but seem to be very uniform in character. Their size is but very little different from that of the posterior cervicals, their length no greater; the venous foramina on the ventral side become gradually more remote from each other.

Some of the *dorsal ribs* were so badly decomposed that they could not be recovered from the matrix; others were so intermingled with other bones that they could not be removed entire. The larger part, however, have been recovered and restored nearly to their living condition. The anterior long ribs are flattened, with an expanded head, only moderately curved and with the distal extremity only a little attenuated, the cartilaginous continuation evidently of some length. The posterior ribs are short, less flattened, with a less expanded head and with a pointed distal extremity. From the position of the diapophyses anteriorly, it is quite evident that the ribs were directed much more outwardly than downwardly. In the restored skeleton, the transition from the long to the short ribs has been made gradual, and two or three on each side have been modeled here. (See Pl. XI.)

---

*Baur (Anatom. Anzeiger ix, No. 4, 1893, p. 120) would restrict this term to the process bearing the head of the rib in the Stapedifera.

†Seeley has proposed to call these vertebræ in which the rib is ascending from the centrum, pectorals.

About fifteen *ventral ribs* were preserved; others have undoubtedly been lost. Only one is symmetrical; it is about thirty centimeters in length and is thickest near its middle, tapering to a point on each side, and has a moderate curvature. The others preserved measure from twelve to sixteen centimeters, and have a thickness near their middle of about ten millimeters. They are gently curved, irregularly prismoidal in section, and taper to a point at each extremity. Because of their number and the scattered positions in which they were found, it has not been possible to arrange them in the mounted skeleton with any degree of precision. In the known European specimens they form a double series of three, with a larger symmetrical median one. Abdominal ribs are known only in the crocodilia, rhyncocephalia pterosaurs, ichthyosaurs, dinosaurs and plesiosaurs.

The *caudal* vertebræ were found at some little distance from the remainder of the skeleton, and for the most part had been collected separately by Mr. Sternberg. The processes, as elsewhere in the column, had been separated, and were, many of them, found variously intermixed with the other bones. Both the centra and the processes, however, were in excellent condition, as were those of the neck, in marked contrast to the dorsal vertebræ. The last twelve taper so uniformly that it is quite certain they all belonged together, and that no intervening ones were missing. This series has a diameter of forty millimeters at the beginning and only twelve at the extremity, with lengths respectively of twenty-five and twelve millimeters. The greatest decrease in size occurs in the last five or six of the series. These distal five or six have the shortening much more pronounced on the dorsal than on the ventral side, indicating a well-marked upward curvature of the extremity of the tail. Because of the rapid change in the characters of these vertebræ there has been no difficulty of associating the processes with their respective vertebræ. The spines in the early ones of the series slope at a moderate angle backward, the obliquity being greatest in the twelfth from the end. In the last six, the spines are much shorter and stand nearly vertically, or even with an anterior slope. The diameter of the last centrum preserved indicates the presence of two, or perhaps three smaller ones forming the extreme tip of the tail; these must have been mere nodules of bone, without processes. (See Pl. X.)

Several other vertebræ are assigned to the caudal series, chiefly on the evidence of the venous foramina on the ventral side of the centra, though they have no facets for the chevrons. Between these and the continuous series, four vertebræ have been intercalated; the number may be too great; possibly not enough. That some were missing is quite certain, since the change in the direction of the spine is too abrupt in the ones preserved. Because the tail as restored seems to be of about the length of some other known forms, I am inclined to believe that the number of the caudal vertebræ, all told, did not exceed twenty-five. All those preserved, except the anterior ones, show a nearly circular and somewhat cupped surface on each side for the attachment of the hæmapophyses. The separate branches are directed downward, outward and backward. They are somewhat flattened and expanded distally, except the distal ones, which are more rod-like. The diapophyses or ribs of the connected series spring from near the middle of the centra dorso-ventrally, and are directed outward horizontally, the most posterior ones also slightly forward. They have a somewhat expanded extremity, with a cartilaginous margin. At the beginning of the series they arise near the middle of the centra antero-posteriorly, but gradually approach the anterior margin. They terminate as free ribs on the seventh before the end, that is on the ninth or tenth before the extreme tip of the the tail. The sixth has a small exogenous tubercle to represent the process. None of the caudal vertebræ, save at the immediate base, have functional zygapophyses, and the tail was evidently capable of considerable lateral and vertical movements. There are no indications whatever of a terminal fin, unless the upward curvature of the tip of the tail suggests such an appendage. Its use, however, could not have been great, since the evident shortness of the tail, and its interference with the hind limbs would have deprived it of much service as a propelling organ.

PECTORAL GIRDLE.—The *scapula* is of the usual triradiate shape. The coracoid or glenoid ramus is short and rather stout, somewhat expanded at the extremity, with the two articular facets meeting in an obtuse angle, the larger, oval one for the glenoid articulation; the smaller, triangular one for union with the coracoid. The dorsal ramus is narrowest, is rather stout, thickened on the posterior and thinned on the anterior border; it terminates in a flattened surface for attachment of a suprascapular cartilage. The ventral or clavicular (proscapular) extremity is broad and thin and deeply concave on its visceral surface. Its inner border is rounded for the most part and thin, except on the anterior part, where it is moderately thickened, as though for cartilage. The posterior and inner border is quite thin throughout and evenly concave, forming the outer anterior border of the scapulo-coracoidal foramen. The anterior border is sinuous and thinned, having a knife-like edge throughout its whole extent. The exterior border, between the glenoid and suprascapular extremities, is deeply concave, with the margin thickened and convex. The ventral surface of the bones forms two nearly flat planes, meeting in a straight, prominent ridge, which extends from the ventral side of the anterior border of the glenoid surface to the anterior angle of the ventral ramus. The two surfaces meet in a very obtuse angle. The visceral surface is, for the most part, concave. On the ventral ramus this concavity is marked, receiving the clavicle on its anterior part. There is a sutural roughening continued along the anterior border

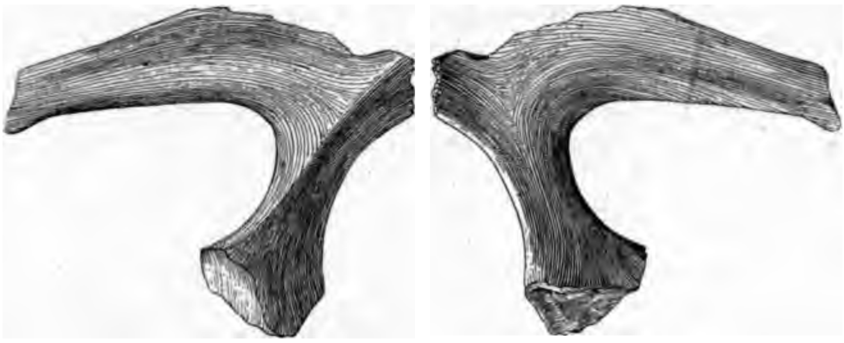


FIG. 6.

Part of right scapula of *Plesiosaurus mudgei* Cragin, external (left, and internal (right) views.

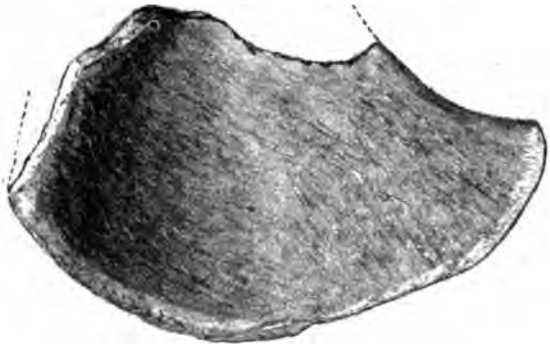


FIG. 7.

Ventral extremity of scapula of *Plesiosaurus gulo* Cope (type specimen), one half natural size.

to the base of the dorsal ramus, throughout the whole extent of the concave portion of the border. The bone differs from the scapula of *Murænosaurus*[*] in the less expanded ventral ramus, which is separated from its mate by the clavicle and episternum. From the *Cryptoclidus*[†] scapula it differs in having a more slender and elongate dorsal ramus, and in the non-expansion of the ventral ramus. From a scapula of *Pl. mudgei* Crag. from the Lower Cretaceous in the University of Kansas Museum, it differs in its much less slender coracoidal and dorsal rami. The bone is also much more slender than in *Peloneustes*. (See Pl. XII.)

The *coracoid* is a very large and broad plate, with a slender, blade-like epicoracoid projection. Its glenoid portion is massive, with a smaller humeral articular surface, and a larger scapular facet, meeting each other in a very obtuse angle. The external border is thickened and concave, produced into a considerable projection at the posterior angle. Just before its termination there are several tooth-like projections of small size, evidently for muscular attachment. The posterior margin is thin, with rounded angles and a slight concavity between them. Opposite the glenoid articulation the bone is massive, meeting its fellow in a thickened bar with an oblique sutural surface. Immediately posterior to this interglenoid thickening, the bone on the mesial side is very thin, and in the anterior part of this thinned portion, near the middle line, there are two large, well-defined, round foramina that have never before been described in the coracoid, though perhaps indicated in the description of *Trinacromerum*. The clavicular or epicoracoid process in front is long and thin, with nearly parallel sides, the anterior end slightly expanded and its margin with a cartilaginous border. The sutural surface for the clavicle extends back on the upper surface to nearly midway of the process. The coraco-scapular foramen is elongate in shape and is bounded entirely by the two bones, save for a short distance at the front inner part where the clavicle completes the margin. The coracoid has the posterior outer angle more produced than in either *Cryptoclidus*, *Peloneustes* or *Murænosaurus*, and the clavicular process is longer and better developed than has been described in any form, except perhaps in *Trinacromerum*.

The *clavicle* is a thin, concave, irregularly triangular or triradiate bone, and is well developed. It lies upon the ventral plate of the scapula and the epicoracoid process of the coracoid, and above the squamous margin of the episternum, a remarkable position for a membrane bone to attain on the visceral side of all three cartilage bones. The anterior border is gently thickened, somewhat sinuous in outline, and is free for a part of its extent. The other borders are thin, for the most part squamous, and nowhere free, save for a short distance at the anterior end of the coraco-scapular foramen, and the posterior part of the interclavicular foramen. The two bones meet

---

[*] Andrews, Ann. Mag. Nat. His. xv, 431.

[†] Andrews, Ann. Mag. Nat. Hist. xv, 355.

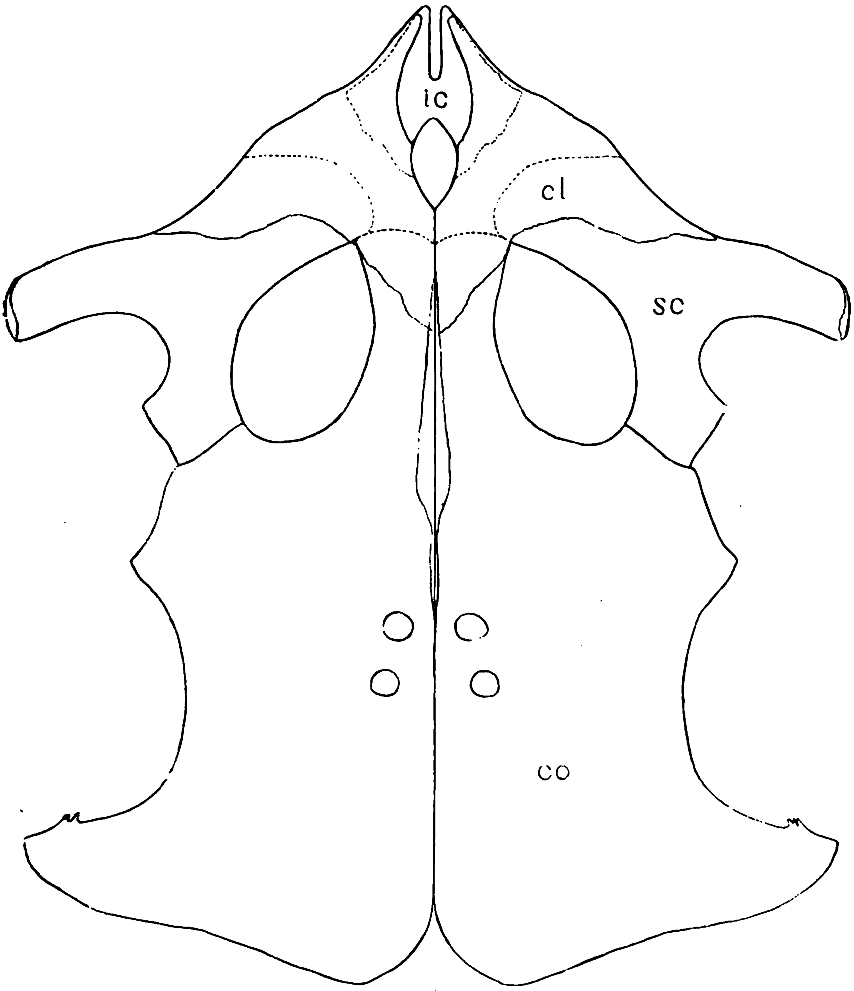


FIG. 8.

Diagram of pectoral girdle of *Dolichorhynchops osborni*, from above, the outlines of concealed parts are indicated by dotted lines. *Ic.*, episternum (interclavicle); *cl.*, clavicle; *sc.*, scapula; *co.*, coracoid.

in a median symphysis for a short distance back of this interclavicular foramen. The under or convex surface appears only for a small space between the ends of the scapulæ, epicoracoid processes and the episternum. Its outer extremity extends into a slender process, broken away in the specimen figured, which reaches along the front margin of the ventral ramus of the scapula to the base of the dorsal ramus. (See Pl. XIII.)

The *clavicle* seems to be the most variable bone in the skeleton: I know of no form in which it is better developed. In *Cryptoclidus* it is a small, triangular bone, meeting its mate in the middle line, according to Andrews, the episternum being absent. In *Plesiosaurus mudgei* Cragin (see Pl. XXVII), the clavicle appears to have been smaller and more triangular than in the present species. It is generally assumed that this bone is the real clavicle by Seeley, Andrews, Fürbringer and others, and one may, with Andrews, explain its position in relation to the ventral ramus of the scapula by the peculiar method of ossification of that bone. But, can its visceral relations to the coracoid and episternum be explained as easily? It is true that many authors call the median, unpaired piece the interclavicle, a membrane bone, and, if this origin is accepted, its position in relation to the clavicle is not remarkable. But I am inclined, with Gegenbaur and Fürbringer, to believe that this central piece is really the episternum, a cartilage bone. Andrews described the clavicle in some forms as showing a sutural tendency with the scapula, and in some forms, as *Elasmosaurus*, it seems to become entirely fused with that bone, or if not, has disappeared entirely.

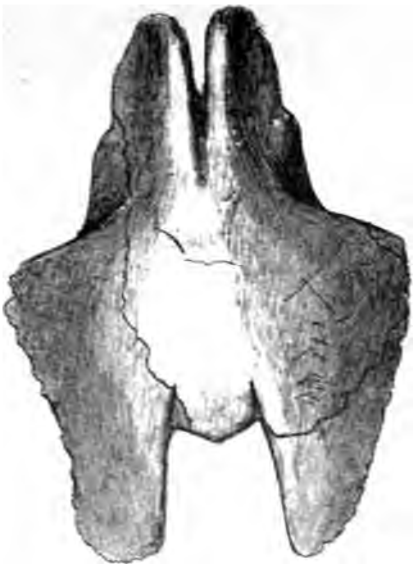


FIG. 9.

[illegible] W: [illegible] natural size.

The *episternum* (interclavicle) is a small, symmetrical bone deeply emarginate in front and behind. The thin squamous margin on each side underlaps the clavicle. These squamous borders seem to have been covered with cartilage below, leaving a free, convex, ventral surface, elongate oval in shape, including the emarginations, limited by a distinct ridge or angle. The striation of this thinned margin points to a covering of cartilage. The anterior emargination of the bone is narrow and deep, while the posterior one is broader and even deeper. It differs markedly from the corresponding bone of *Pl. mudgei* (see Pl. XXVII), in its less broad and deep emarginations. An episternum which I provisionally refer to the species *Tr. anonymum*, herewith figured, resembles that of *D. osborni* more closely. In all three, perhaps belonging to distinct genera, it will be seen that

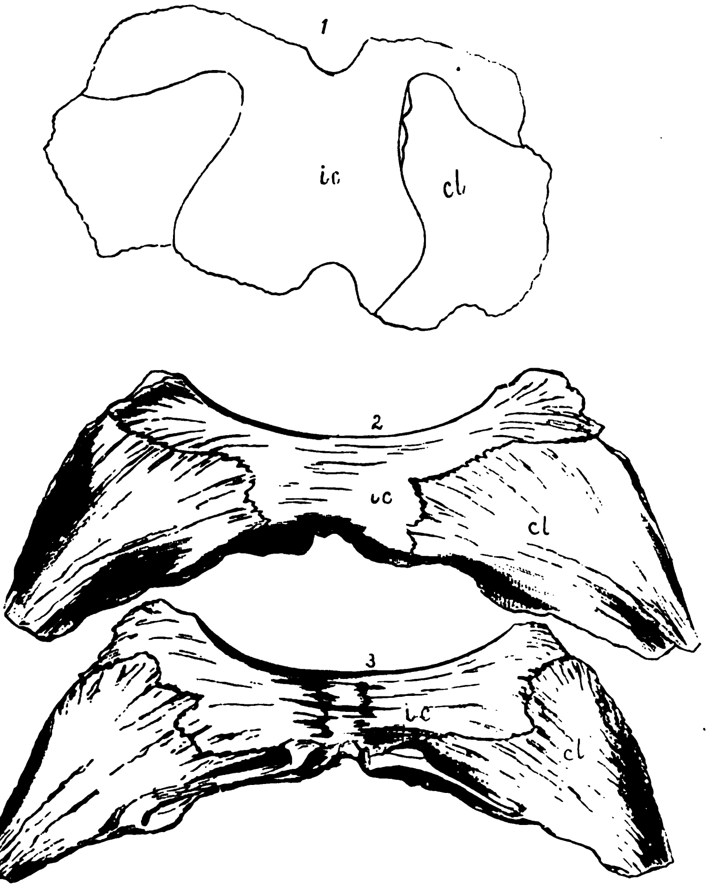


FIG. 10.

1. **Episternum and clavicles of *Muraenosaurus*; 2. 3. the same of *Plesiosaurus*, from above and below. After Seeley.**

the emargination behind represents a distinct foramen in the completed girdle —the interclavicular foramen, of which the only mention hitherto that I can find is by Seeley (Proc. Roy. Soc. Lond. li, p. 140), whose figures I reproduce here.

In Pl. XV is shown the articulated pectoral girdle from below, and in Pl. XIV, the same is shown in front view. As a whole, the girdle forms a rather deep trough, with the dorsal rami of the scapula directed upward and somewhat outward. Its exact position in relation to the ribs is difficult to state, but I do not think that the position given in the restoration can be far wrong. The slight degree of curvature of the ribs in the pectoral region must have left a rather angular margin to the thorax on either side, filled in, in part at least, by the cartilaginous continuation of the thoracic ribs, which the preserved ends plainly show were present. The upper surface of the girdle was not hollowed much, if any, longitudinally, so that the base of the neck must have been in life quite deep.

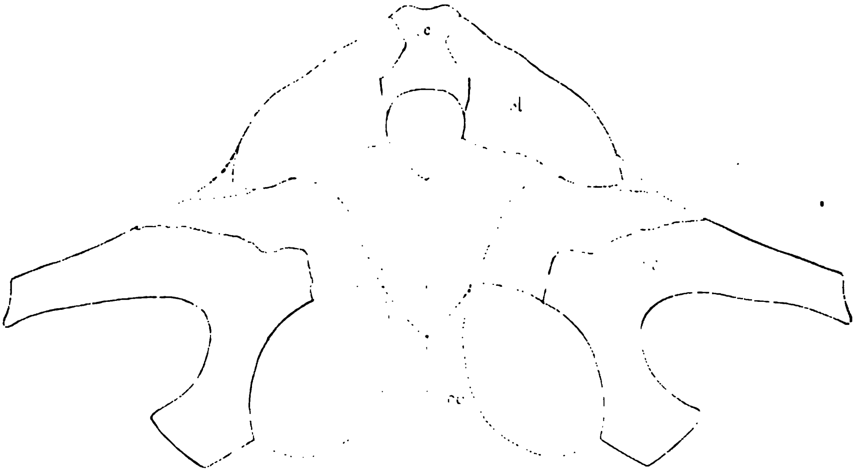


FIG. 11.

Scapulo-clavicular girdle of *Plesiosaurus mudgei* from above; the missing parts restored in dotted lines. *Ic.*, episternum; *cl.*, clavicle; *sc.*, scapula; *co.*, epicoracoid process.

An examination of the under surface of the girdle, as shown in Pl. XV, furnishes, I think, convincing proof that the space between the scapulæ, epicoracoid process and the elliptical lines on the ventral surface of the episternum was filled in in life by cartilage, joining the coracoid and scapula and covering the squamous portion of the episternum, but leaving the interclavicular foramen free. Ossification of this cartilage evidently occurs in some forms, uniting the whole into a single ventral plate, which is said to have a sutural connection with the epicoracoid processes, forming what Seeley calls the Elasmosaurian type of girdle. Seeley suggests that this cartilage may represent the precoracoid: "In all Plesiosaurs, on the other hand, the precoracoid, if developed, remains cartilaginous; but I infer that a cartilage always extended from the anterior margin of the coracoid to the anterior extremity of the scapula, and, by ossification of such cartilage, the Plesiosaurian shoulder girdle would become Elasmosaurian."*

This precoracoid nature of the cartilage is contested by Koken: "The view that the bone considered to be the scapula in the Plesiosaurs also includes the precoracoid is supported neither by comparison nor observation. In no reptile has there been shown to be a union of the scapula with the precoracoid more intimate than its union with the coracoid, and its fusion with the scapula without union with the coracoid would be remarkable. I agree quite with Baur, who considers the forked bone of the turtles to be the scapula only, its two branches being homologous with those of the plesiosaurian scapula. Seeley believes that the precoracoid was cartilaginous, connecting the front end of the coracoid with the anterior end of the scapula, and that this became ossified in the Elasmosaurians in such a way that it was separated from the coracoid by suture, but was fused with the scapula. That is, it is the precoracoids and not the scapulæ which meet in the middle line. It seems to me that this would be the method of extension and ossification of the scapulæ. Why, then, should we call in the aid of a cartilaginous precoracoid as an unknown quantity, which later becomes indistinguishably fused with the scapula?"†

The precoracoid arises from a distinct ossificatory center, when ossified. Is it reasonable to suppose, then, if this is a distinct element, that any such mode of extension of the scapula as Andrews has shown to be the case in *Cryptoclidus oxoniensis*‡ would occur if there was really a union of scapula and precoracoid? He shows clearly that the scapula increases in length peripherally, and not by the addition of an ossified cartilage. If it arose from a distinct center, as it must, one would certainly expect to find it in a separated condition in the young animal, but this was not the case in the ones that Andrews examined. Furthermore, in what possible way could a cartilage bone like the precoracoid get entirely on the outside and seal in a membrane or dermal bone? I would sooner believe that the so-called clavicles are really precoracoids, and for this belief their position on the visceral side of all three cartilage bones, the scapula, episternum and coracoid, would lend some support. In no case, however, can I believe it probable that this cartilage represents the precoracoid.

---

*Proc. Roy. Soc. Lond. li, p. 138, 1892.

†Koken, Zeitschr. Deutschen Geol. Gesellsch. 1893. xlv. 346.

‡Ann. Mag. Nat. Hist. 1895.

The same argument will apply in its entirety to the assumption that the ventral ramus of the scapula is in reality the precoracoid. In no specimen has it ever been found as a distinct ossification. It grows peripherally, enclosing the clavicles on their outer side. The elongated clavicles unite by suture with the scapula in the Nothosauria without the intervention of any precoracoid process. By the reduction of the clavicles and the extension of the acromial process in these animals we would get the Plesiosaurian girdle. Is it necessary to insert a distinct ossificatory element in this development?

It may be added that Koken believes the precoracoid to be fused with the coracoid.

I cannot, therefore, believe that the precoracoid is represented by any ossification in the plesiosaurian clavicular girdle. Nor do I believe there is any genetic relationship between the ventral ramus of the Plesiosaurs and that of the Chelonian scapula. If there is, is it not strange that in the one case the branch should lie ventrad to the clavicle and in the other dorsad? I am well aware that in thus concurring in the views held by Seeley, Andrews, Koken, Baur and others, there are pertinent arguments on the other side given by Hulke, and especially Fürbringer.*

Pelvic Girdle.—The *pubis* varies but little from the usual form. It is a broad, flattened plate of bone, thinned throughout, except at the symphysial and acetabular articulations. It is, in general, quadrilateral in shape, with the anterior inner angle broadly rounded, and the acetabular angle truncated. The posterior and outer borders are both markedly concave, and of about equal length. The anterior border is more nearly straight and irregular. The inner border is thickened on the posterior third or half, gradually becoming thinner anteriorly. The obliquely truncated sutural surface is much roughened. The two bones, when united, must have made an angle with each other of about one hundred and twenty-five degrees. I do not think that there was much cartilage between the two, or that it extended back to the ischial symphysis, though it may. Anteriorly

---

Jena. Zeitschr. 1900, p. 332.

the cartilage continued to the rounded outer anterior angle, where the bone is a little more thickened. The acetabular surface is much the larger of the articulating facets. It meets the smaller and roughened facet for the ischium in a very obtuse angle. The bone is more thickened on the outer and posterior parts, that is, near the non-cartilaginous border, than elsewhere. (See Pl. XVI.)

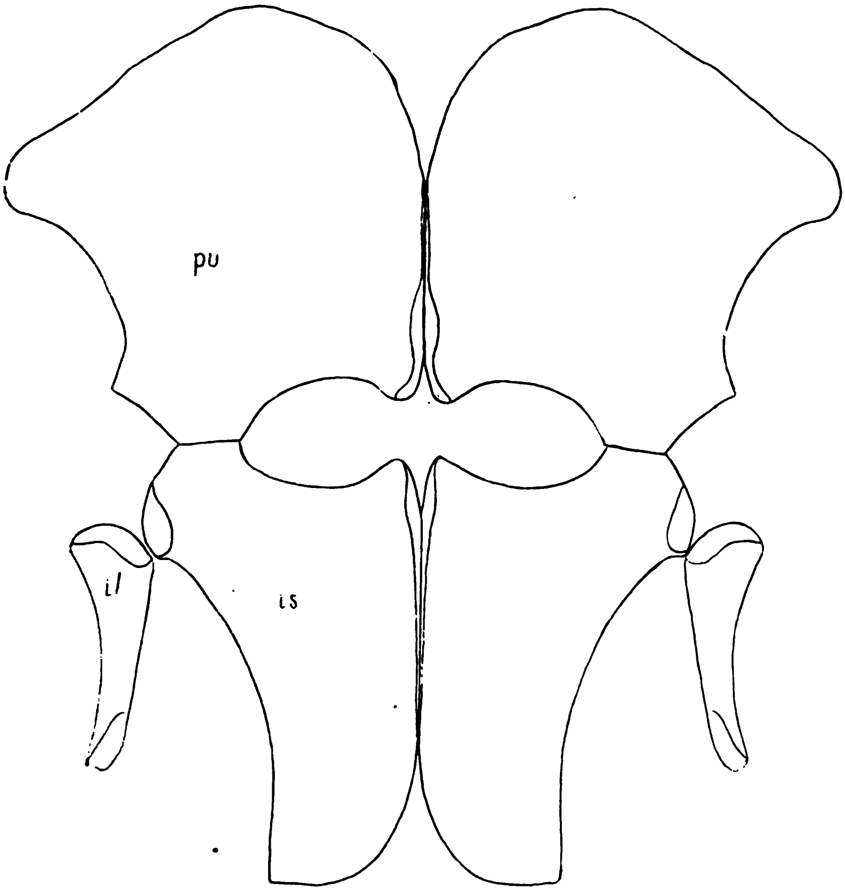


FIG. 12.

Diagram of pelvic girdle of *Dolichorhynchops osborni*, visceral surface. *Pu.*, pubis; *is.*, ischium; *il.*, ilium.

The *ischium* is more elongate and proportionally larger than is usual among plesiosaurs, though of the usual hatchet shape. It has three non-sutural articular surfaces—the larger middle one, looking directly outward in the articulated ischium; a smaller posterior one, looking upward; and a small one looking forward and a little downward for the pubis. The anterior border is concave, and the portion adjacent to this border is the thickest of the bone. The symphysial border is thickened on the anterior third, gradually thinning posteriorly. This border is obliquely truncated, as in the pubis, anteriorly; posteriorly the cartilaginous border, moderately thin, is continued around the inner angle to the outer one, where it meets the free outer border abruptly. The outer border is gently concave in its whole extent, and only a little thicker than the inner portion of the bone. It ends in a right angle. (Pl. XVII.)

The *ilium* is a small, rod-like bone, moderately expanded at its ischial extremity. Of the two articulating extremities, that for the ischium is much larger than the one for the acetabulum. In the middle of the bone, a cross-section is roundly oval. The upper extremity has a small, flattened, parallelogrammatic surface, which, in the articulated pelvis, looks inward, slightly backward, and perhaps a little downward. The bone when articulated was directed backward at an angle of about thirty degrees, and inward perhaps a little more. There is very little evidence of articulation with the sacral ribs. The union must have been weak and slight.

The pelvis, as a whole, was troughlike, as was the pectoral girdle. The two bones meet at a considerable angle, and it is also certain that there was a large angle between the ischium and pubis, so that, with the ischial symphysis nearly horizontal, the pubes were directed at a considerable angle downward. This position, indeed, is necessary, since otherwise there would have been a strongly upward turn of the abdominal contour immediately behind the coracoids, and the ischia and pubes will articulate in this position only in this specimen.

FRONT LIMBS.—The paddle-bones of the specimen were all completely intermingled and displaced, so that none could be referred to its proper limb from the position they were in.

Apparently nearly all were preserved, though some of them were distorted and crushed. The labor of assorting and correctly locating these parts was very great, especially the phalanges; indeed, of the latter there is little assurance that the final collocation in many cases is correct. Aside from the femora and humeri, the only distinction that could be made between the bones of the front and hind limbs was in the size, always slightly smaller in the hind than in the fore limb. By thus assorting into pairs and assigning the smaller pair to the hind limb it was certain that the bones of the epipodial and mesopodial regions were correctly placed. The labor was much lightened by the aid of a nearly complete paddle of another species, described further on. This paddle was less compressed and distorted, and I have therefore reserved it for a more full description of the parts and discussion of the functions.

The humerus of *Dolichorhynchops* has the head only moderately convex, with its margins rather sharply limited, its greater convexity, as usual, on the radial side; its general surface looks mesad and ventrad at an angle of about forty-five degrees. Its cartilaginous surface is continuous with that of the tuberosity, which has a large, flat surface, directed dorsad and mesad at an angle of about forty-five degrees. The grooves separating the surface from the head are broad and shallow, that of the ulnar side the broader. The anterior border of the bone is concave on the proximal part, gently convex at the middle and shallowly concave on the distal part. The posterior border is nearly straight on the shaft, deeply concave distally. The distal anterior angle is rounded in both specimens. On the distal border two facets are apparent, for the radius and ulna; the rest of this border presents no clear indications of articulations. The pectoral rugosity is strongly roughened, and produced into a broad, low tubercle; the roughening, moreover, is continued obliquely nearly to the other rugosities on the sides. It is situated nearer the head than in *Polycotylus*. The ulnar rugosity forms a deep pit above the middle of the bone, while the radial rugosity is opposite it and much nearer the head of the bone than in *Polycotylus*.

Three bones were certainly located in the fore-arm, and a fourth one seems to be represented by a pair of small nodules. The free, emarginate border between the radius and ulna is less apparent than it is in *Polycotylus*. The relations of all the smaller bones seem to be quite as they are in *Polycotylus*, and the reader is referred to the figures of the two paddles for comparison, in connection with the description of that of *Polycotylus*.

HIND LIMBS.—The femur shows the usual plesiosaurian differences from the humerus, in its greater slenderness, slightly greater length, more slender shaft and less dilated distal extremity. The anterior border, as seen in the figure, is nearly uniformly concave, terminating in a more pronounced angle than in the humerus. The posterior border is, also, concave throughout to the greatest expansion, which occurs more proximally than in the humerus, and in a rather better marked angle. The rugosities of the under side and margins are as in the humerus, though scarcely as well marked. Whether the bones of the leg and ankle have been correctly located, rather than in the fore limb, is impossible to say—the only differences that could be detected are the rather lighter weight or greater slenderness of those located here. Their relations to each other are precisely those of the fore limb. It seems probable that the fourth bone on the posterior side of the first row, articulating with the femur, was wanting in life, or at least was very small—none were preserved. The fore and hind limbs, as restored, are of the same length. All four paddles were restored as completely as those shown in the figures.

CIMOLIASAURUS SNOWII.

SKULL.—The skull of this species was briefly described by me in the Transactions of the Kansas Academy of Science for 1890, to which some additional observations were made by Cope in the Proceedings of the American Philosophical Society for 1894, p. 109. I give here a more complete comparative description, in the light of the information furnished by other known forms, especially *Dolichorhynchops*.

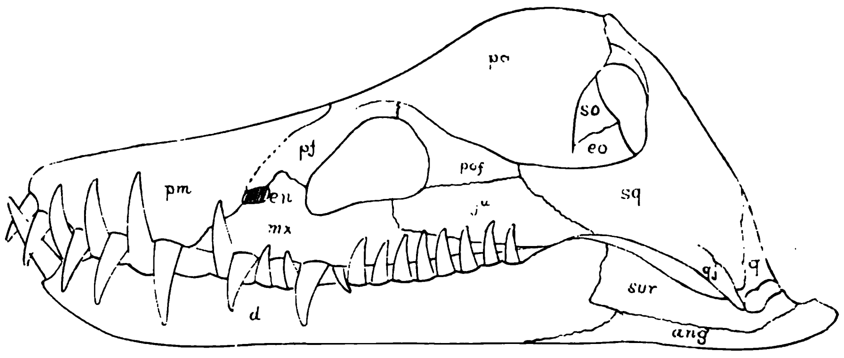


FIG. 13.

Skull of *Cimoliasaurus snowii* Will. *Pm.* premaxilla; *en.*, external naris; *mx.*, maxilla; *pf.*, prefrontal; *pof.*, postfronto orbital; *j.*, jugal; *sq.*, squamosal; *pa.*, parietal; *so*, supraoccipital; *eo.*, exoccipital; *q.*, quadrate; *qj.* quadratojugal; *d.* dentary; *sur.*, surangular; *ang.*, angular.

The *parietals* form a steep, roof-like covering, ascending into a thin, sharp, sagittal crest, extending through nearly their whole length, from the attachment of the squamosals posteriorly as far forward as the posterior part of the orbit. This crest, throughout most of its extent, forms a thin, vertical plate, with nearly parallel sides for about two inches, its thickness on the margin varying from two to four millimeters. Posteriorly they expand into a thickened, triangular process on each side, projected downward and backward over the supraoccipitals for union with the squamosals. Extending the whole length of the crest is a well-marked suture. Near the anterior extremity of the crest is the parietal foramen, which has been closed by compression.

The postorbital appears as a narrow bar directed outward and downward. Its union with the supraorbital above and the squamosal below is shown in the figure. The bone is triangular in shape, as seen externally, the suture for the jugal extending back horizontally. and is then turned upward at right angles to meet the free margin of the arch.

The suture separating the *jugal* from the squamosal begins at the angle of the postorbital suture and runs obliquely downward and backward to meet the lower border of the arch about fifty millimeters back of the teeth. The suture is a jagged one, but its existence as described and figured is beyond doubt. Professor Cope figured it much further back on the arch, but his supposed suture is very plainly a fracture. The bone unites below with the maxilla by a long, nearly horizontal suture, that begins in an angle a little back of the middle of the orbit and joins the alveolar margin near the last tooth. The anterior part of the suture is nearly at right angles to the remainder, joining the orbital margin back of the middle of the orbit.

The *squamosal*, or squamoso-prosquamosal. is a large, triradiate bone joining the jugal and the postorbital anteriorly, the parietal above, the quadrate and quadratojugal below. Cope has figured the upper branch as a distinct bone under the name of supramastoid. This was an error, as has already been stated. At the anterior inferior part of the quadrate there is a distinct suture, as has been figured, corresponding to the suture described as existing here in the specimen of *Dolichorhynchops*. In the figures given of *C. snowii*, it was supposed that the quadratojugal was a small element. It now seems probable that its relations to the squamosal are like those of *Dolichorhynchops;* at least there is an indication that the real suture is continued upward and forward for some distance. The union of the squamosal and quadrate is very much as it is in *Dolichorhynchops*.

The *quadrate* does not seem to differ from that described in *Dolichorhynchops*.

The *premaxillary* is very large and massive. Its dentigerous portion is broad and thick, with numerous pit-like depressions. It contains six very large and powerful teeth on each side, the maxillary suture beginning just back of the sixth tooth. The distinguishing suture turns upward and backward to meet the anterior end of the external nares in front of the orbit. Above this, for a short distance, the bone is so crushed that the suture is not determinable with certainty, but the upper end is evident, nearly above the middle of the orbit. The suture separating the two premaxillæ is distinct throughout.

The *maxilla* has on each side sockets for twelve or thirteen teeth, all, except a few of the anterior ones, much smaller than those of the premaxilla, and smaller than those of the mandible in this region. From the nares, which are chiefly excavated from this bone, the suture turns upward and backward for about twelve millimeters, separating the nasals; it then turns downward and backward to join the anterior orbital margin, uniting with the prefrontal. The lower anterior margin of the orbit is thus formed by the maxillary plate, which shows a shallow groove. The maxillary plate on the left is smooth and undistorted, the nasal and prefrontal having been separated at their sutures. There is no indication whatever of a separation into two elements, nor is there any free lachrymal. Posteriorly the maxilla forms a rather broad plate below the orbits, having a convex thinned margin continuous with that of the jugal. Back of the middle on this margin, the suture for the jugal turns directly downward for about twelve millimeters, and then backward in a straight line to terminate just beyond the last tooth.

That element which, in *Dolichorhynchops*, is described as the *supraorbital*, is a much more massive bone in *Cimoliasaurus*. It unites with the postorbital by a strong suture, behind the middle of the orbit above, and is not separated by a deep notch as in that species. The bone arches forward and downward to beyond the middle of the anterior part of the orbit, as in *Dolichorhynchops*, standing out prominently over the orbit and terminates in a strong suture by which it is united to the ascending plate of the maxilla, as has been described. Its union with the prefrontal or frontal cannot be determined in the crushed state of the specimen. Such relations of a supraorbital bone with the postorbital, maxilla, nasal, etc., are almost inconceivable, but are altogether right for a prefrontal. If this be a prefrontal, then the same element in *Dolichorhynchops* must also be the prefrontal, and the so-called postprefrontonasal is in reality the frontal, while the anterior prolongation from the parietal is in reality a process from that bone, separating the frontals, a most remarkable arrangement for any vertebrate skull. I am forced to believe, however, that such is really the explanation of these bones.

The *supraoccipitals* are visible from the side behind and are not covered over by the wing-like expansions of the parietals, as in *Dolichorhynchops*. They are paired and separated throughout, as in that genus. Below they unite with the exoccipital, and include a part of the semicircular canals. Above and in front they join the parietals at their posterior margin and not under the roof. The exoccipitals are also visible. The paroccipital process is slender, its posterior margin thin, joining the supraoccipital in an angle without the small excavation which is seen in *Dolichorhynchops* at this place.

Lying within the orbit are thirteen thin, bony *sclerotic* plates, the largest about twenty millimeters in diameter, with somewhat crenulated margins. The larger number are lying in position, imbricated with each other.

There are sockets in the mandibles for nineteen or twenty teeth on each side. Those in the upper jaws seem to be the same in number, though the small posterior ones are so covered by the inferior teeth that the number cannot be positively determined. The largest teeth implanted in the upper jaw are those of the premaxilla; back of these there is but a single large tooth, situated just in front of the orbit. The largest teeth of the mandible are the ones corresponding to those of the premaxilla; the posterior ones, however, are much larger than the corresponding ones of the upper jaw. The anterior teeth, especially, are elongate, conical and lightly recurved. All are sharply pointed, with the crown, within a half or three-fourths of an inch of the socket, finely striated. The largest is that of the premaxilla just in front of the maxillary suture, which measures fifty-three millimeters in length by thirteen in width at the base of the crown. The first tooth in the mandible is fully as long, though a little more slender.

The *pterygoids* are so crowded in between the mandibles and maxillæ that only a portion of them is visible. The posterior part joins the quadrate by a stout plate, as in *Dolichorhynchops*. By the sides of the sphenoids the plates are broad and massive, with a thinned outer crenulated margin. The *ectopterygoid* unites with the jugal and maxilla. Evidently there are elongated interpterygoid vacuities, as in *Dolichorhynchops*.

The mandible, from the tip of the symphysis to the hind extremity, measures 480 millimeters, of which the teeth occupy 320. Its least width, near the middle, is 40 millimeters; its greatest width, just back of the teeth at the coronary eminence, is 75 millimeters. The length of the symphysis is 65 millimeters. The two sides are firmly coössified, traces of the suture being visible in the posterior part only. The sutures separating the angular, surangular and dentary are shown in the figure.

CERVICAL VERTEBRÆ.—There were twenty-eight cervical vertebræ in a continuous series preserved, the last five or six, owing to exposure, in a less perfect condition: the others complete or nearly so. Traces of the sutures uniting the neural arches with the centra can be observed in the third and fourth vertebræ only. The atlas and axis are so wedged in the compressed occipital region that the former bone can not be distinguished, and the latter is visible in part only. The third vertebræ, herewith figured, differs from the following ones in the greater obliquity of the spine, in the more oblique anterior face of the centrum, in the presence of a conspicuous carina below in front, and in the simple, pointed shape of the single-headed rib. The fourth vertebræ has the neural process less oblique and broader, the carina in the middle of the concavity of the under surface not visible from the side; the rib is broad and of nearly equal width throughout. In the sixth vertebræ and beyond the neural process is broader and nearly vertical; the ribs are broad, with more marked anterior and posterior prolongations distally. The spines increase in width throughout the series, but are only a little longer posteriorly. The posterior centrum is more than three times the length of the anterior ones and the diameter posteriorly is more than twice that anteriorly. The ribs of the posterior vertebræ are but little longer, though much wider, than those of the anterior vertebræ. The following measurements will exhibit these differences in size more exactly:

NUMBER OF VERTEBRA.	3	4	6	9	14	20	27
Length of centrum	23	30	48	53	63	78	90
Height of centrum	25	27	42	44	50	60	68
Height of spine above floor of neural canal	55	46	47	47	50	62	. . .
Width of spine	. . .	24	36	40	42	65	. .
Length of rib	. . .	40	. . .	40	48	. . .	. . .
Width of rib	. . .	24	. . .	40	56	65	. .

BRACHAUCHENIUS LUCASI, GEN. ET SP. NOV.

The specimen upon which this genus and species are based is one of much interest, not only because of its excellent preservation and preparation, but also because of the new features which it presents. It consists of the skull, neck, and larger part of the dorsal column, all lying together in their natural relationships, and all with the ventral surface exposed, in the prepared specimen. The specimen was collected some years ago near Delphos, in Ottawa County, Kansas. Its horizon is the Benton Cretaceous. It is now preserved in a wall-case in the National Museum. I desire to express my hearty thanks to the authorities of the National Museum for permission to study and describe the specimen, and especially to Mr. F. A. Lucas for much kind assistance. It gives me great pleasure to honor, in the specific name, one who has done much valuable work in American paleontology. (Pls. XXIV, XXV.)

SKULL.—The palatal surface of the skull lies exposed, with the mandibles in position. There has been but little distortion or displacement, the mandibles being slightly depressed and pushed to the left. The limestone matrix has been carefully removed from most parts, leaving the bones entirely clean. The sutures are entirely clear, and there are but few adventitious fractures to obscure the relations of the parts. It is certain that additional excavation will reveal further characters of importance, but not many, unless the specimen be entirely removed from the matrix. The specimen as now mounted in the wall slab makes a very interesting and instructive display, but I believe that some day it will be advisable to remove it entirely from its limestone bed and mount it after the manner of a recent skeleton. It was fortunate, however, that this was not done before a careful examination had been made of the natural relations of the bones, as it would have been difficult to believe that the neck comprised but thirteen vertebræ, had not the matrix conclusively demonstrated the fact. It is the shortest-necked plesiosaur known, differing in this respect not greatly from the short-necked aquatic saurians of other orders.

The *pterygoids* extend far back to unite with the lower end of the quadrates, apparently quite as usual in the plesiosaurs, though the precise place of junction is obscured by the mandibles; the process is slender. The two bones meet in a median suture on the under side of the sphenoid, their posterior border forming a wide and deep concavity. The outer margin of the bones converge from the quadrates as far forward as the posterior end of the interpterygoid vacuities, where they curve outward into the posterior border of the ectopterygoid processes. The under surface is shallowly concave on either side back of the vacuities, but in the middle there is a rather strong, obtuse ridge. A little back of the vacuities, on either side, with their origins separated, a narrow and strong ridge arises to curve outward and become lost on the under border of the somewhat descending ectopterygoid process. In front of the vacuities the two bones again meet in a long median suture. The palatal surface here occupies a somewhat higher plane than that of the posterior part, and is flat throughout. The bones of the two sides gradually narrow in width to terminate by an obtuse extremity near the middle of the palate. Between the ectopterygoid processes and between the curved ridges already described there is a narrow, deep vacuity, with two oval, elongated, well-defined foramina or vacuities at the bottom, the "palatonares" of Owen, the "posterior palatine vacuities" of Andrews, the "interpterygoid vacuities" of authors. A discussion of their character will find a place further on. The lateral walls of this fossa posteriorly are nearly vertical, but the anterior end of the fossa is but little or not at all excavated above the plane of the palate here. From the anterior end of the median posterior interpterygoid suture two sutures diverge, leaving a large angular sloping surface exposed which forms the posterior roof of the fossa; the bone exposed between the V-shaped sutures is the basisphenoid, and has attached to it by suture the so-called parasphenoid bone in front. Just how the diverging sutures terminate I cannot definitely say. They seem to follow the lower angle of the lateral wall of the fossa as far forward as the middle of the vacuities and thence return to join the parasphenoid suture at the posterior part of the vacuities. If this determination is correct, these projections would correspond to the basipterygoid processes of the lizards. The ectopterygoid processes of the pterygoids, the continuation of the curved ridges, have a rounded, prominent under border, with a terminal, large, vertical or oblique, abutting, mandibular surface. This ridge and its abutting surface are very much as they are in *Pliosaurus*, and the whole structure here also reminds one of the crocodiles.

The transverse, transpalatine or *ectopterygoid* bone is a rather small, flattened polygonal bone, whose under surface is continuous with that of the palatine and pterygoid in front. It joins the pterygoid on the inner side and behind, the posterior suture descending on the side of the projecting process of the pterygoid. To what extent the bone enters into the abutting surface for the mandible I could not determine. Anteriorly the bone joins the palatine by a clearly marked suture. Its outer border posteriorly is rounded and seems to be free, forming a part of the border of the posterior palatine vacuity, but this can not be determined without further excavation of the matrix. The outer attachment of the bone (doubtless to the jugal and maxilla) cannot be determined.

The *palatines* are long flat bones which meet for a considerable distance in a median suture in front of the pterygoids, a feature hitherto unknown among the plesiosaurs. In front this median suture divaricates to admit the pointed extremities of the vomers. A little distance from the interpalatine suture, near its middle, there are, on either side, two or three small, round foramina. The outer border of the palatines continues the border of the ectopterygoids throughout and is continuous, apparently with the lateral border of the vomers. How far this apparent border in the specimen represents the real border of the bone cannot be determined without additional excavation of the matrix, here filling in a narrow space between the apparent margin and the mandible. It is possible that there may be no free border, though I think it probable that there is a smaller or larger posterior palatine vacuity on each side posteriorly. It is probable that the sides of the bones turn upwards to meet the maxillæ in the way they are figured by Sollas in *Plesiosaurus.**

The posterior pointed extremities of the *vomers* are seen in the middle in front, enclosed between the V-shaped suture of the palatines. The suture seems to be visible to the border of the palatine and includes no part of a narial opening. The nares hence must be situated far forward between the vomers and the maxillæ. Unfortunately this part of the skull has been injured somewhat before removal, and the complete structure here cannot be determined.

The so-called "*parasphenoid*" is different from that element in other plesiosaurs. It is a single bone separating the interpterygoid vacuities. As seen from below, it is spindle-shaped, narrow in the middle, moderately expanded at either extremity. Posteriorly it is joined by a clearly marked suture with the basisphenoid. Anteriorly it joins the two pterygoids in the entrant angles, but does not extend much, if any, beyond the angle. The vacuities separated by this bone are long and oval, situated at the bottom of the fossa already described, between the pterygoids and in front of the basisphenoid. It would seem that there could be no further question as to the character of these vacuities—simply fortuitous openings—separated by a remarkably persistent, well-ossified parasphenoid, invariably found in all plesiosaurs, but never in their nearest allies, the turtles and nothosaurs. In most of the plesiosaurs in which the palate is known, the openings are situated more nearly upon the plane of the palate, and, though somewhat variable in shape, are always of moderate or considerable size. In this species, however, they are at the bottom of a well-marked, rather deep fossa, with well defined lateral walls and a sloping posterior roof.

---

*Quart. Journ. Geol. Soc. 1881, p. 475, f. 12.

These foramina in the plesiosaur skull were first thought to be the nares by Owen, who, however, confounded the anterior part of the pterygoids with the palatines. Huxley, who was also not clear about the palatines, suggested that the real internal nares were smaller openings situated more anteriorly. Sollas (l. c.) discussed the matter more at length and reached the conclusion that the real internal nares were situated far in front, between the premaxilla and vomer, with the palatines probably entering into the posterior border. Andrews has accepted this location of the nares, and has figured and described the openings in three genera of the plesiosaurs, always bounded by vomer, palatine and maxilla. In *Dolichorhynchops osborni*, however, as seen from the figure and descriptions, these openings can only be situated between the vomers and palatines and at some distance from the maxillæ. In my description I accepted these orifices as the true nares, though greatly astonished at their minute size, and although they correspond with similar foramina between the vomers, in the mosasaurs.

If we are to seek for the nares in their present specimen elsewhere than in the openings I have described it must be far forward, perhaps in precisely the position assigned to them by Sollas. In all the known forms, with this interpretation, they would be in front of the external nostrils, in the present species far in front. What possible combination of circumstances would have caused the recession of the external nostrils to a place so close to the orbits without affecting the position of the internal openings? I certainly suspect that in this species at least the openings between the pterygoids are the real internal nares. As to the character of the separating element I am forced to the conclusion that Andrews has reached, that it is the parasphenoid. If the element in front called the vomers are really those bones, and there could seem to be no doubt that they are, there is nothing else left, save possibly the turbinated bones. The slender bone in precisely similar position in the ichthyosaurs is usually called the presphenoid. Such perfect and persistent ossification of the parasphenoid, scarcely found elsewhere among the reptilia, unless it be the snakes, is in any case remarkable. Why should it be persistent in separating such persistent foramina, unless the openings were of functional importance? One would expect that the pterygoids would have united along the whole median line, as in the Nothosauria, or that they should have closed up in front of the basisphenoid, as in the Chelonia. Sollas objects to this posterior position of the nostrils, because there is no ossified canal for the air passages, as in the crocodiles; but his specimen, as ours, would call for a canal running in the opposite direction, from the posteriorly situated external nares anteriorly to the internal openings, and, in the present species, this canal would have been eight or more inches in length. And why may not the canal have been cartilaginous in either case?

MANDIBLE.—The mandibles are nearly in place on the under side of the skull. They are a little compressed from above downward. The symphysis is short, the two jaws meeting in a considerable angle. The portion in front of the posterior end of the symphysis has been somewhat injured in the specimen, so that the precise shape and length can not be ascertained. The angular extends posteriorly into a relatively short process; the expansion below the cotylar cavity is rounded. In front of the cavity, the angular extends forward to within six inches of the symphysial angle, terminating in a slender, sharp end. From a little in front of the middle of the ramus it is excluded from the inner surface. In front of the cotylar cavity the greater width of the outer surface is composed of the surangular. Between these two bones, the dentary sends a long, slender process backward to within six inches of the cotylar cavity.

Length of skull to end of mandible	1.1 m.
Length of skull to condyle	.9 m.
Width of skull between outer margins of quadrate . . .	.28 m.

VERTEBRÆ.—The atlanto-axial complex is thoroughly united, without indications of sutural division. The axial rib appears to be united with the axis only, though it may come in contact with the axial intercentrum. The atlas is convex from side to side, without indication of a median carina. The other cervical centra, as seen from below, are nearly flat, with a slight convexity in the middle, and a slight concavity on either side before the sutural surface for the rib. This flatness is a natural character and not due to compression. The median convexity increases gradually throughout the cervical series.

The increase in length of the cervical vertebræ is slight, as will be seen from the table of measurements. The articular margin of the vertebræ, throughout both the cervical and dorsal series, is sharp, not rounded for a continuation of the cartilaginous surface, as is so often the case among plesiosaurs. The ends, as seen in the third vertebra, are distinctly though not deeply concave. The ventral vascular foramina, so characteristic of plesiosaur vertebræ, appear to be wanting throughout the whole series, nor is there the slightest indication of a median ridge and lateral grooves. The lower margin of the rib articulation approaches the ventral plane in the early cervicals, but ascends somewhat on the sides of the vertebra in the last cervical.

Twenty-two dorsal vertebræ are preserved in natural sequence. Because of the decrease in the length of the transverse process in the late dorsals, it does not seem probable that more than eight or ten presacral vertebræ could be missing, making altogether about thirty, the usual number of dorsal vertebræ. The length of the centra increases more rapidly, though gradually, in the early dorsals, and then remains constant throughout the remainder of the series. The centra are deeply concave below and on the sides, expanding outwardly on the sides above to meet the sutural surface for the arch. The surface of the centra is nearly smooth, with but slight indications of crenulations before the articular margins.

RIBS.—The ribs throughout are single-headed, and of the usual plesiosaurian type, though proportionally short in the thoracic region. The axial rib is flattened spatulate at the distal extremity; massive at the proximal. The lower surface is nearly flat, the upper surface deeply concave, the anterior border gently, the posterior border deeply concave. The rib of the third vertebra is more expanded distally, with the distal posterior margin somewhat more produced, and the distal border thinned. The fourth rib is more expanded distally, with a more pronounced distal expansion, and the distal border seems to be thickened for cartilage. The next four or five ribs differ only slightly from the preceding ones. The rib of the tenth vertebræ is more elongated and slender. The attachment to the centrum is sessile or nearly so, the head inserted in a shallow pit. In the eleventh vertebra there is a distinct exogenous process, standing out twenty or twenty-five millimeters from the surface of the centrum to the end of which is attached the rib. This process is equally as prominent, or more prominent on the next two centra, the twelfth and thirteenth. The rib of the twelfth vertebra is intermediate in length between that of the eleventh and of the thirteenth. On the last cervical centrum, the thirteenth, the twelfth rib is long, heavy and stout, more than half the length of the first dorsal. It is nearly as stout as any of the following, but tapers somewhat distally, though ending in a truncated, cartilaginous extremity. The distal end of the eleventh rib is lost. The first dorsal rib resembles the one preceding it, though longer. The second dorsal rib has acquired nearly the full length of the thoracic series. In the ninth rib there is a beginning of a diminution in size; the rib is less thick, a little shorter, and less expanded at its extremity. The twelfth rib is completely preserved; it is yet smaller and thinner than the eleventh, though still possessing a cartilaginous extremity. Of the following ribs, only the heads of some are preserved.

DIAPOPHYSES.—The diapophyses occupy an unusually low position on the arch of the whole dorsal series, as do also the cervical ribs. They have not been wholly freed from the matrix, and their relation to the articular process is determinable only in slight part in a few of the posterior vertebræ. The arch, like the cervical ribs, is united by a strong, persistent suture, evidently an adult character, since the sutures of the atlanto-axial complex have been entirely obliterated. The process of the first dorsal is short, compressed, and somewhat expanded at each extremity; it clearly springs from below the dorsal surface of the centrum. As already described, the last cervical rib, but little shorter than the first dorsal rib, is attached to a short process which arises, apparently wholly, from the centrum. The diapophysis of the first dorsal is less than twice the length of this process, and so much like it that its sutural connection with the centrum is the chief distinctive difference. The second dorsal diapophysis is a little stouter than, and about twice as long as the first. Its articular surface for the rib is larger, flattened, and looks downward and outward. The fourth and fifth processes have attained the maximum size of the series. They have a narrow, concave ventral border, more strongly concave posterior border, a flattened, expanded proximal end for union with the centrum and an expanded distal extremity with its flattened oblique costal surface. The height of the process distally, and its expansion beyond the plane of the articular zygapophyses, can not be determined. It is very evident, however, that the diapophyses lie below the plane of the zygapophyses, in which they differ markedly from the diapophyses of *Dolichorhynchops*, where, throughout most of the dorsal vertebræ, they are placed wholly above the plane of the zygapophyses. The succeeding diapophyses, to the sixteenth dorsal, scarcely differ in their shape and relations to the centrum. These vertebræ may, therefore, be properly called thoracic. From the seventeenth vertebra to the last one preserved, the twenty-second post-cervical, the diapophyses decrease rapidly in size, the last being scarcely more than half the length of the fourth or fifth. In these posterior processes the proximal articulation of the arch is as broad as in any of the others, but the distal end of the process is more compressed, with only a small surface for the small presacral ribs. Over the twentieth vertebra the matrix has been cleared away sufficiently to disclose a posterior zygapophysis. The free diapophysis in this vertebra is about fifty millimeters in length, thirty in height, and about twenty in width. The posterior zygapophysis arches upward and backward from the base of the free process.

MEASUREMENTS.

	Length of Centrum.	Width of Centrum.	Length of Rib.
Atlanto-axis,	90 mm.		
Third cervical,	46		
Fourth cervical,	46	82 mm.	60 mm.
Fifth cervical,	44		
Sixth cervical,	45		
Seventh cervical,	47		
Eighth cervical,	50	84	74
Ninth cervical,	50		
Tenth cervical,	50		
Eleventh cervical,	53		94
Twelfth cervical,	58		
Thirteenth cervical,	60		220
First dorsal,	64	85	260
Second dorsal,	68		370
Third dorsal,	73		400
Fourth dorsal,	74		490
Fifth dorsal,	77		445
Seventh dorsal,	77	82	370
Twelfth dorsal,	77	82	370
Twenty-second,	74	82	

LENGTH OF DIAPOPHYSES.

First,	47 mm.	Fourth,	90 mm.	Eighteenth,	75 mm.
Second,	65 "	Fifth,	95 "	Twentieth,	65 "
Third,	80 "	Thirteenth,	90 "	Twenty-second,	60 "

Among the characters which have been given in the foregoing descriptions there are some of more than usual importance, of more than generic value. It is quite evident that the form can not be placed in the same family with *Dolichorhynchops* or *Cimoliasaurus snowii*. Just what family this may be I can not say at present. It is very evident that we have to do in the plesiosaurs with several distinct families, but the material is hardly sufficient yet to clearly define them. Several names have already been proposed, based upon partial characters, but there is no unanimity in their acceptance, nor can there be until much more is known about these animals than is the case at the present time.

The essential characters of the present genus, so far as known, may be summarized as follows: Head large and broad; palatine bones broadly contiguous; a strong pterygoid ridge on either side; a deep interpterygoid fossa; neck very short; cervical ribs single-headed; cervical ribs and vertebral arches united by persistent suture; no infracentral vascular foramina.

Many of these characters, possibly the union of the palatines in the median line, are those of *Pliosaurus:* but *Pliosaurus* has the anterior cervical ribs double-headed, a character supposed to be of at least family, possibly subordinal value. Of this, however, I am very skeptical, and it is possible that a final classification may locate this genus with the Pliosauridæ.

It is very evident that the elongation of the neck is a specialized character in the plesiosaurs, since we can not conceive of any animal with so many vertebræ in the cervical region from which these animals could be derived. Considering this character alone, *Elasmosaurus* would be the most specialized of all the plesiosaurs, and *Brachauchenius* the most generalized. It is a question, however, whether such forms as the present have preserved this primitive character from their terrestrial ancestors, with only a slight increase in the number of the cervical vertebræ, or whether there has been a secondary reduction in the number from some long-necked ancestor. That the long-necked plesiosaurs are not all specialized throughout, is very evident. In the species of *Plesiosaurus*, a genus of long-necked forms, the epipodial bones are far more generalized in character than are these bones in the short-necked *Polycotylus*, where the epipodials have become not only broader than long, but have actually increased in number to four. That an increase of the number in the cervical vertebræ is a specialized character has already been affirmed by Baur, Dollo and Fürbringer in the Dolichosaurs.

It seems also evident that monocranial ribs are a specialization.

not only in these, but in other aquatic air-breathing vertebrates, such as the cetacea, some ichthyosaurs and the mosasaurs, due to environmental causes. It is true that all the Squamata show the same single-headedness of the ribs, brought about by similar conditions—the lack of the necessity of support of the abdominal organs by the ribs in animals resting prone upon the ground, or in a medium of nearly the same specific gravity as the creatures themselves.

It is a singular fact that, in many plesiosaurs, vestiges of dicranial ribs have been retained in the neck, though such have disappeared elsewhere in the vertebral column; and this character has been retained in both the long-necked and the short-necked types, such as *Plesiosaurus* and *Pliosaurus*, though utterly wanting in others, such as *Elasmosaurus* with seventy-two cervicals and the present with only thirteen. Did the long-necked forms become differentiated before the dicranial character was lost, and have they continued as a distinct phyllum until the character was wholly lost? If so, the short-necked Pliosaurs must represent a distinct branch of the order which has also undergone the same change.

The Cretaceous plesiosaurs of America, so far as known, are all cercidopleural, while many of the European Jurassic forms are dicranopleural.

This is the fourth species of plesiosaur that I know from the Fort Benton deposits of Kansas; there are none certainly referred to this epoch from other regions, though *Brimosaurus grandis* Leidy is probably of this horizon. The only one of these hitherto described is *Trinacromerum bentonianum* Cragin, a long-headed form with long mandibular symphysis and short neck, a form indeed approaching, possibly identical with *Dolichorhynchops*. Another form known of which a considerable part of the vertebral column is preserved at the museum of the University of Kansas, is of great size, the dorsal centra measuring five inches or more in diameter, with a very long neck and small anterior cervicals. The specimen is from near Beloit. It represents a distinct species that may provisionally be referred to *Cimoliasaurus* or *Brimosaurus*. A third form is much smaller, about the size of *Dolichorhynchops osborni*, with short neck. The episternum is shown in Fig. 9 and the cervical vertebræ and humerus in Pl. XXVIII. I suspect that it belongs in *Trinacromerum*, though smaller than the type species. I have called it provisionally *Trinacromerum anonymum* n. sp. From all these forms the one described may be at once satisfactorily distinguished by the entire absence of infra-central vascular foramina.

That the species described in the foregoing pages belongs in some genus named but not recognizably described from a later epoch is not probable, though possible. I have therefore given the genus the name *Brachauchenius*.

POLYCOTYLUS LATIPINNIS.

PADDLE.—Some years ago an excellent specimen of a paddle of a plesiosaur belonging in all probability to *Polycotylus latipinnis* Cope, was collected by Mr. George R. Allman of Wallace, Kansas, from the upper Niobrara chalk of the Smoky Hill river, east of Fort Wallace. The bones of the paddle were, for the most part, found in their natural relations, but were separated in the collection of them. The radius and ulna of a second paddle, together with some of the smaller bones showed weathering, and doubtless had been picked up from the surface. It has required but little trouble to fit into their natural relations all the bones except most of the phalanges, which, presenting no lateral surfaces for articulation, could only be located from their other characters. A careful study of these, however, makes it probable that the positions assigned to them in the photograph are for the most part correct. Because of the considerable expansion distally of the long bone, the paddle is supposed to be the front one, but it is quite possible it may be a hind one. Pl. XXI.

The head of the *humerus* is large and broad, of a flattened ellipsoidal form, with the surface nearly evenly convex; it is slightly crushed dorso-ventrally. The tuberosity, placed at a slight distance beyond the plane of the proximal extremity, is massive. It has two, large, flattened, narrowly separated surfaces for muscular attachment, placed nearly at right angle to the longitudinal plane of the bone and separated from the head by a slight groove on either side, that of the ulnar side being the more pronounced. On the ulnar side of the tuberosity there is a slight rugosity, as though for muscular attachment. The shaft is narrowest near the upper third of the bone, where a cross-section would be nearly circular, or slightly greater in its dorso-ventral diameter. The anterior or radial border is gently convex on its upper two-thirds, gently concave below to the rectangular angle. The posterior border is more deeply concave throughout. The distal border has a deep, cupped, thickened facet at right angles to the dorso-ventral plane, for the radius; a second shorter and less thick one for the ulna joins this at a small angle; beyond this, the thinned ulnar expansion is lost in the specimen, but doubtless had two facets for the third and fourth bones of the epipodial row. On the ventral surface of the bone above, proximad to the middle, there is a large, stout rugosity for muscular attachment. The very strong muscle attached to it doubtless arose from the ventral surface of the coracoid. On the ulnar border of the bone, at its middle, there is a more pronounced, though smaller rugosity, for muscular attachment. The peculiar tooth-like projections on the outer posterior angle of the coracoid described in *Dolichorhynchops osborni* probably indicates the origin of the muscle inserted into this rugosity. It may be called the ulnar rugosity. On the radial border, a little beyond its middle, there is a smaller and less strong rugosity which may be called the radial. The origin of the muscle inserted here probably was on the lower part of the scapula. The dorsal surface of the shaft is smooth, without muscular roughening beyond the tuberosity. The distal portion of the bone is much expanded, thickest toward the radial side, and moderately thinned at the distal outer margin.

Of the four muscular rugosities, which doubtless furnished attachment for nearly all of the muscles controlling the arm, those of the tuberosity are of course the largest, though the large roughening on the ventral side may have been for the insertion of more powerful muscles, which were of course much more effective from the greater mechanical advantage under which they acted. The movement here, though strong, could not have been through a great range. The smallest of all, and placed much further away from the fulcrum is the radial. The great convexity of the head indicates considerable freedom of rotation. The glenoid surface in the articulated skeleton of *Dolichorhynchops* looks nearly directly outward. The obliquity at which the head of the humerus is placed as regards the horizontal plane, indicates that the natural resting position of the flipper was at about forty-five degrees downward, but I doubt whether the extremities of the paddles could have been raised much, if any, above a horizontal position. It is further certain that the flippers could not have been brought back against the side of the body. The posterior angle of the coracoid, projecting as it does beyond the plane of the glenoid surface, certainly prevented any great backward movement of the humerus. It seems also evident from this position of the coracoid, that the paddle was not so pedunculated as restorations usually have them, but that the humerus was largely or entirely hidden in folds of the skin, as was evidently also the case, not only in the ichthyosaurs, but also in the mosasaurs.

The largest bone beyond the humerus is the *radius*. It is irregularly four-sided in shape; the longest and convex proximal surface fits into the radial facet of the humerus; the shortest and non-articular border, that adjoining the ulna, is emarginated like its opposing border to form with it a small foramen. Doubtless these two emarginations represent the last vestige of the terrestrial type of the epipodial bones. The outer border of the radius, the second in length, is non-articular and thinned, and has an acute angle proximally. The outer distal margin is thick for articulation with the radiale of the carpus. The inner distal border, next to the shortest of the four, is for articulation with the mediale.

The *ulna* is next in size to the radius, and is irregularly six-sided. The largest, proximal border, is convex, like that of the radius, and joins the smaller facet of the humerus. The distal border has three facets of nearly equal length, and joining each other in nearly equal angles. These façets are for the mediale externally, the ulnare in the middle, and for the ulnar supernumerary, internally. On the inner side there is a longer but thinner border for articulation with the first epipodial supernumerary, while the outer border is emarginated like the opposing border of the radius.

The next bone of this row, articulating with the humerus, and of considerable size, is one of doubtful homology. I will call it the first epipodial supernumerary. If one follows Marsh in his views of these corresponding bones in *Baptanodon*, then this bone is the ulna, and the one here called the ulna is the medial carpal. But this interpretation is very doubtful. Zittel thinks this bone in the ichthyosaurs is the pisiform, while Woodward calls it the sesamoid; but I doubt these interpretations as well. Among the cetacea, the mosasaurs, ichthyosaurs and plesiosaurs there is a reduplication of bones, which have been variously explained as a splitting of the phalanges, either directly or through the intervention of the epiphyses. The latter view is hardly possible, since there are no epiphysial ossifications in most if not all these reptiles, and besides, there would not be enough epiphyses on the normal digit to furnish the great number of phalanges seen in some of the forms. The extra digits in some ichthyosaurs are also explained by the longitudinal division of the normal phalanges; but I cannot believe that this is the correct explanation. I believe that the supernumerary digits, phalanges, epipodial or mesopodial bones found in such species as this, as well as in most other American plesiosaurs, represent entirely new ossifications in cartilaginous

POLYCOTYLUS ISCHIADICUS, N. SP.

I give this name provisionally to a species from the Niobrara Cretaceous of western Kansas, represented by a number of bones in the University of Kansas Museum, the most characteristic of which are shown in Pls. X and XXVI. There is no assurance whatever, however, that they belong in this genus; on the other hand they may belong with the type species, *P. latipinnis*, or they may belong to some unrecognized genus. The ischia, it is seen, differ very markedly from the corresponding bones of *Dolichorhynchops osborni* in the shorter length of the symphysial portion, in the greater breadth of the neck, and in the smaller extent of the cartilaginous rim posteriorly. The bones are also more massive and the face for the ilium is larger. The ilia also are materially different, in the greater expansion proximally, and in the absence of the lateral angular face distally. They have a somewhat curved neck, with a rounded head showing a cartilaginous surface. The transverse processes of the sacral vertebræ are more massive than in that species, with a considerable expansion proximally, a cylindrical shaft and a terminal, somewhat oblique face for articulation with the ilium. The somewhat compressed sacral vertebra is shown from its ventral surface.

A specimen from the Niobrara in the Kansas Museum, comprising a number of caudal vertebræ and a portion of the pelvis, I refer with much more assurance to *P. latipinnis* Cope. The vertebræ differ very materially from the present, and the probability is, therefore, that *P. ischiadicus* is not a synonym of *P. latipinnis*.

PLESIOSAURUS GOULDII.

Plesiosaurus gouldii Williston, Kansas Univ. Quart. vi, p. 57, Jan. 1897.

Among the material collected in the Lower Cretaceous shales of Clark county, Kansas, by Prof. C. N. Gould, and now preserved in the museum of the University of Kansas, are the remains of at least three different forms of Plesiosaurs, all, however, represented by rather incomplete material. Portions of one of these forms (*Plesiosaurus mudgei* (?) Cr.) are figured elsewhere in this paper; another was briefly described by me several years ago under the name of *Plesiosaurus gouldii.* The species is referred to *Plesiosaurus* because no better place is known for it; in all probability it really belongs to some other genus. The species was based upon several dorsal vertebræ in fairly good preservation, one of which, the best, is herewith figured. (Pl. XXVII.)

The specimen shows little compression, and its form is doubtless normal. The anterior face is rather deeply concave, cordate in outline, with a small neural depression above. The anterior zygapophyses are spout-like, the notch between them not extending further than the middle of the articular surfaces. The spine is rather short and small. The transverse processes are compressed, springing in part below the neural canal from the base of the arch. The body is compressed in the middle, forming an obtusely rounded surface below. About midway on the sides, below the lower root of the transverse processes, the side is pinched in, with a small vascular foramen at the bottom of the depression.

The vertebra described probably belongs near the sacrum. Its measurements are as follows:

Width of anterior end of centrum	110 mm.
Vertical diameter, same end	75
Length of centrum	79
Height of vertebra	175
Expanse of transverse processes	175
Width of neural canal	30
Expanse of anterior zygapophyses	50

PROPODIAL BONES OF YOUNG PLESIOSAURS.

It is an interesting fact that isolated propodial bones of young plesiosaurs are not at all rare in the Kansas chalk; no more so indeed than are bones of the adult animals. I have seen more than a score of such, and four or five are now preserved in the museum of the University of Kansas; there are many others in the Yale museum. Four of these bones are shown in Pl. XXIII; a fifth one, more immature than any of those, is figured in Pl. XXII, Figs. 1-4. All such bones are composed of more dense tissue than is observed in adult bones. Especially is the structure dense in the youngest specimen here figured. In this specimen the head of the bone is not at all differentiated, nor are there any muscular markings. On the posterior border, near where the ulnar rugosity should be, there are the openings of two large canals, one on either side of the margin (*b* and *c* of the figures). On what seems to be the ventral surface, near the front border of the bone and nearly opposite the other openings, there is a large one with its mouth, as in the others, directed distally. On the dorsal surface, and near the middle transversely, there is a fourth opening, much smaller than the others. All of these canals unite near the center of the bone in a rounded cavity or ampulla, as shown in Figs. 3 and 4. In Pl. XXIII, Fig. 1, a large opening is seen on the posterior border below a rugose space, and another opening is seen towards the front leading into a groove. This was apparently a canal leading into a groove on the opposite side of the bone in the uninjured specimen, with another opening corresponding to the foramen which lead into a groove shown in the photograph on the exposed surface of the bone. The bone was, however, injured before I studied it, as is indicated by the restored border in the figure. The posterior opening probably corresponds to the united *b* and *c* of the other figures. In Fig. 2 of this plate is also seen a foramen on the posterior margin of the bone (the left one of the figure). All these three bones are probably humeri. Figs. 4 and 5 of the plate do not show these canals; from their shape they are probably femora. In Fig. 1, Pl. XXII, there is seen at the lower margin a groove (e), partly converted into a canal, which probably corresponds to one or the other of the grooves of Fig. 1, Pl. XXIII. I believe this groove corresponds to the ectepicondylar groove or foramen of the chelonia, lacertilia, Belodon, Champsosaurus, and some of the nothosaurs and ichthyosaurs. I may add that a similar groove is sometimes indicated in the humerus of the mosasaurs, as shown in Pl. XLIV, Vol. IV of the University Geological Survey of Kansas. Why these canals and grooves should disappear in the adult humerus is not apparent: they are doubtless for the passage of vessels. The ampulla at the junction of the four canals in the embryonic bone is between the apices of two conical "epiphyses," the larger epiphysis occupying the chief part of the distal portion of the bone, the smaller one the proximal. The fractured specimen discloses these epiphyses with a smooth rounded surface, as shown in Pl. XXII, Fig. 3, the outer part peeling away as does the bark from a tree.

This ephiphysial-like method of ossification has been compared with a somewhat similar structure in the Chelonians as an evidence of relationship between the two orders of reptiles.

A PECULIAR FOOD HABIT OF THE PLESIOSAURS.

More than twenty years ago, Professor B. F. Mudge published, in the First Biennial Report of the Kansas State Board of Agriculture (p. 62), the following: "In the Plesiosaurs we found another interesting feature showing an aid to digestion, similar to that of many living reptiles and some birds. This consisted of well-worn siliceous pebbles, from one-fourth to one-half an inch in diameter. They were the more curious, as we never found such pebbles in the chalk or shales of the Niobrara." The specimens which led to this conclusion were collected while I was a member of Professor Mudge's party, and are now preserved in the Yale collection. Nearly ten years ago some plesiosaur bones collected near Ellsworth, Kansas, from the Benton limestone, were sent to the Kansas University museum, together with a lot of siliceous stones, with a request for information concerning both. At the first opportunity I visited the locality whence they had been discovered and collected what had been left of the specimen. The bones were in a poor state of preservation, due to the effects of frost, but by carefully digging over the shale in which they occurred we obtained about one hundred and twenty-five of the pebbles, together with several dorsal vertebræ and ribs. Some of the pebbles were still attached to the ribs by the original matrix, making it certain that their deposition was contemporaneous with that of the skeleton. The plesiosaur is one of the largest of the order, the dorsal centra measuring five or more inches in diameter. In all probability the species is identical with that mentioned in the preceding pages as coming from the vicinity of Beloit. It is impossible to determine the genus, and the species is yet undescribed. The pebbles vary in weight from less than one gramme to more than one hundred and seventy grammes. The smaller ones were worn into more or less perfect ellipsoids, but the larger ones are more irregular in shape, having suffered less abrasion. It seems probable that the most of the pebbles had been obtained by the animal from the sea beaches bordering the Black Hills, but not a few of them, consisting of red quartzite, are quite identical with the quartzite boulders so often found in the drift of eastern Kansas, which have come from the vicinity of Sioux City, Iowa.

The specimens show conclusively that the pyloric orifice of the plesiosaurs must have been well provided with a sphincter, and that no solid substances passed into the intestinal canal. One need never expect to find plesiosaur coprolites containing undigested remains of bones or other solid material.

The nearest place where the animal could have found such pebbles on the sea beaches must have been several hundred miles away from Ellsworth, where the animal finally perished. We may conclude, hence, that the plesiosaurs were roving animals.

Since the discovery of this specimen two others with siliceous pebbles have been received at the Kansas University museum, one from the Niobrara of Kansas and the other from the Comanche Cretaceous of Clark County, Kansas (Pl. XXIX.) In neither of these cases were the pebbles worn into such regular figures as in the Benton specimen, and all the pebbles were dark in color, none of them quartzite.

What the use of these pebbles was I will not venture to say. They may have served as a sort of weight to regulate the specific gravity of the animals, or they may have been swallowed accidentally. If, as I believe probable, the plesiosaurs were in the habit of feeding upon invertebrate animals, seeking such in the shallow muddy bottoms, the pebbles may have been taken with their food unintentionally. I doubt this, however. I may add that all specimens do not reveal similar pebbles. In the specimen of *Dolichorhynchops osborni*, described in the preceding pages, where one would certainly expect to find them, there were none. Possibly it was only the broad-headed and more omnivorous kinds that resorted to this peculiar diet, the long-snouted types being more exclusively fish-eating in habit.

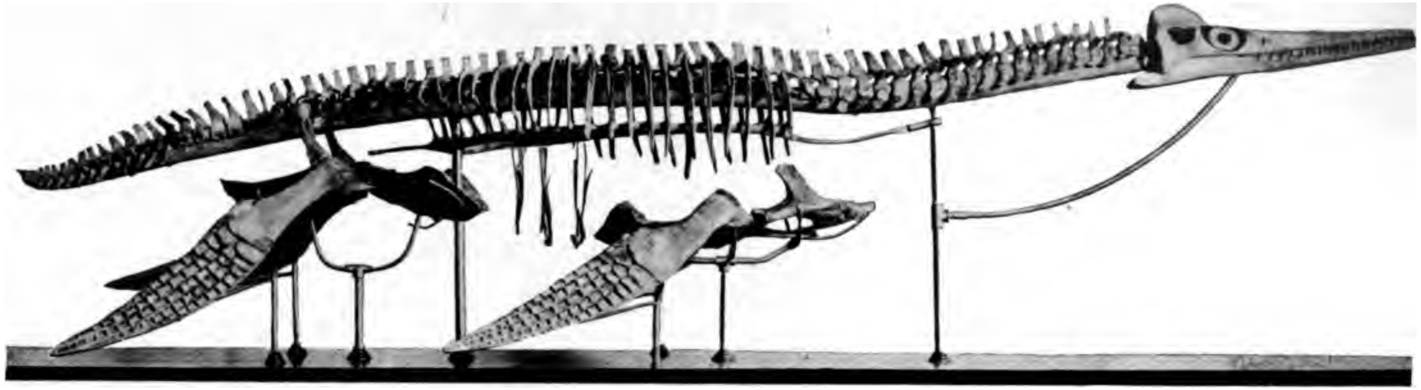
Crocodiles and seals are said to have similar habits, but I have not learned the reason therefor.

Many years ago, a similar habit was recorded of the teleosaurs by Geoffroy St. Hilaire, in the Memoires de l'Acad. des Sci., xxii, p. 48, 1833. Of the plesiosaurs, the only recorded notice, other than by myself, that I can find of such habits is the following by Seeley (Quart. Jour. Geol. Soc., xxxiii, 1877, p. 546):

"In the lower dorsal region of the animal (*Muraenosaurus gardneri*) about a peck of ovate and rounded pebbles occurred, varying in size from a diameter of a quarter of an inch to a length of nearly two inches. They are chiefly of opaque milky quartz, several are of black, metamorphosed slate, and a few of altered, fine-grained sandstone and ironstone, some of the pebbles showing a veined character, such as might be derived from the neighboring Paleozoic rocks of the north of France. Pebbles being of such rare occurrence in the Gault, it would seem natural to account for these associated ones by the hypothesis that they were swallowed by the animal with food, as is the case with several living reptiles and birds. If this view should be held admissible, it would suggest that, as the teeth were too small for anything but prehension, a structure analogous to a gizzard or the stomach of an edentate, may have used these pebbles to assist in breaking up or crushing the food on which the saurian lived."

PLATE I.

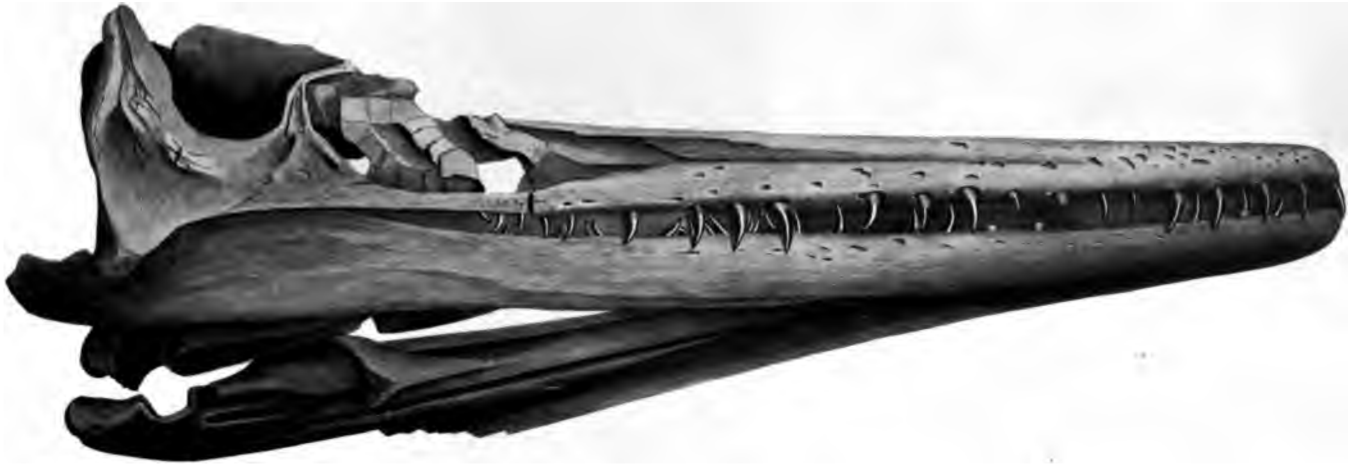
Skeleton of *Dolichorhynchops osborni*, as mounted; 1/16 natural size.



SKELETON OF DOLICHORHYNCHOPS OSBORNI.

PLATE II.

Skull of type specimen of ***Dolichorhynchops osborni***, from the left (reversed). ×7/24.



SIDNEY PRENTICE, DEL.

SKULL OF DOLICHORHYNCHOPS OSBORNI.

PLATE [illegible]

Skull of *Dolichorhynchops osborni*. [illegible]

Fig. 1, type specimen, from the right.

Fig. 2, restoration, from the left.

ang, angular; d, dentary; ex, exoccipital; ept, epipterygoid; f, frontal; [illegible] mx, maxilla; n, nasal; p, parietal; [illegible]; pt, pterygoid; pl, palatine; pm, premaxilla; pf, prefrontal; pof, postfrontal; [illegible]; q, quadrate; [illegible]; s, sclerotic plates; so, supraoccipital; sq, squamosal; [illegible]; v, vomer.

PLATE III.

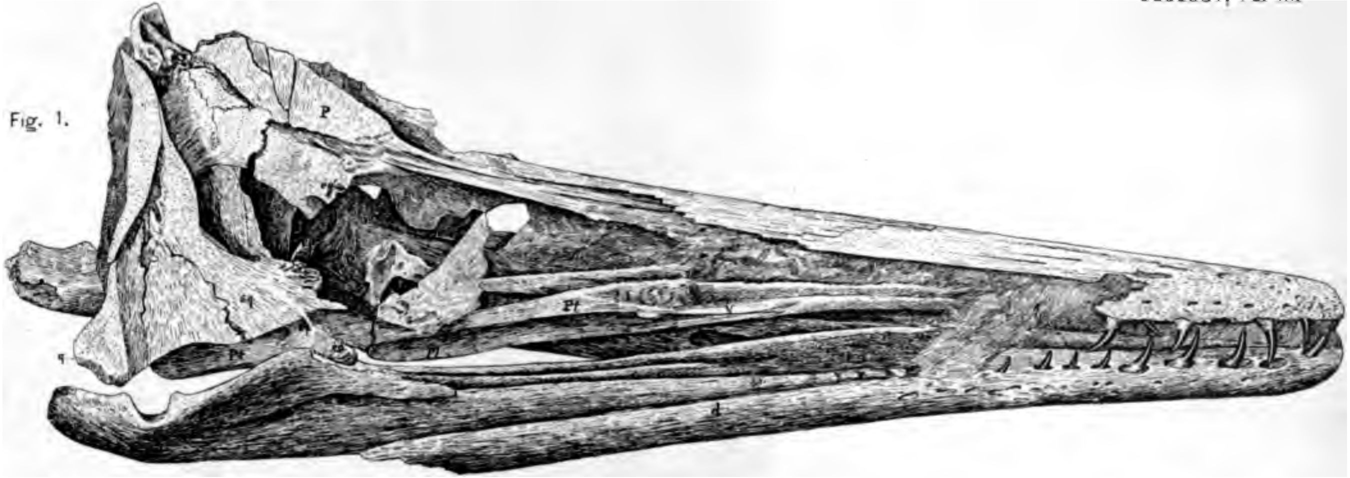
Skull of ***Dolichorhynchops osborni.*** ×7/24.

Fig. 1, type specimen, from the right.

Fig. 2, restoration, from the left.

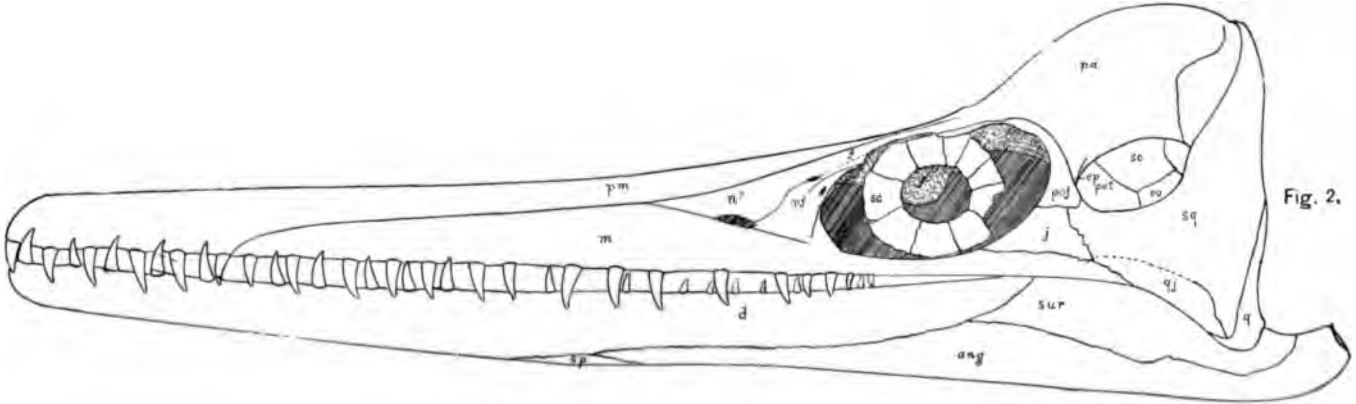
ang, angular; ***d***, dentary; ***eo***, exoccipital; ***ep***, epipterygoid; *f*, frontal; *j*, jugal; ***m***, maxilla; ***n***, nasal; ***pa***, parietal; ***pet***, petrosal; ***pt***, pterygoid; ***pl***, palatine; ***pm***, premaxilla; ***pf***, prefrontal; ***pof***, postorbital (postfronto-orbital?); *q*, quadrate; *qj*, quadratojugal; *sc*, sclerotic plates; *so*, supraoccipital; *sq*, squamosal; ***sur***, surangular; *v*, vomer.

Fig. 1.



SIDNEY PRENTICE, DEL.

Fig. 2.



SKULL OF DOLICHORHYNCHOPS OSBORNI.

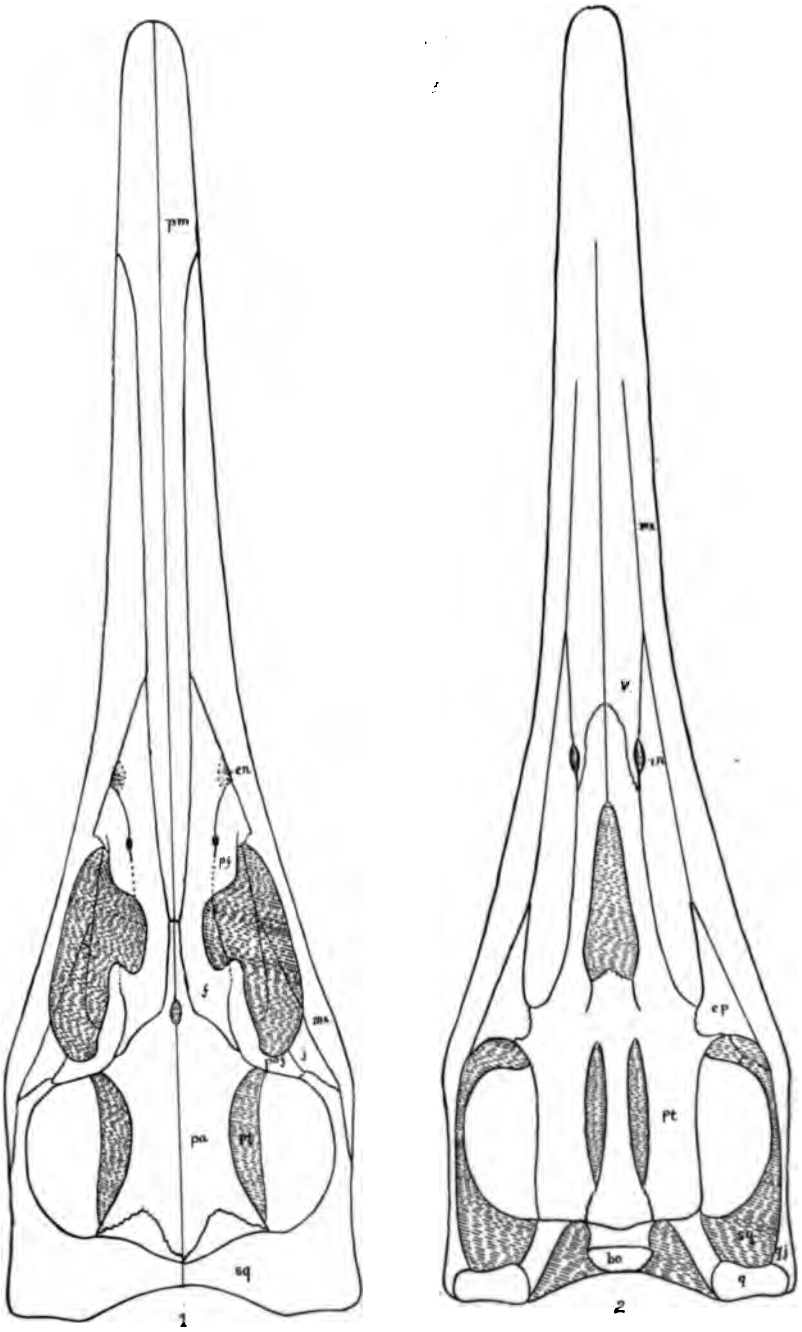
PLATE IV.

Skull of *Dolichorhynchops osborni.* × 1/3.

Fig. 1, from above.

Fig. 2, from below.

bo, occipital condyle; *en*, external nares; *ep*, ectopterygoid; *f*, frontal; *in*, internal nares (the letters are on the anterior end of the palatine); *j*, jugal, *mx*, maxilla; *pa*, parietal; *pf*, prefrontal; *pm*, premaxilla; *pt*, pterygoid; *pof*, postorbital; *q*, quadrate; *qj*, quadratojugal; *sq*, squamosal



SKULL OF DOLICHORHYNCHOPS OSBORNI.

PLATE V.

Inner side of the left mandible of various reptiles.

Fig. 1, *Sphenodon.*

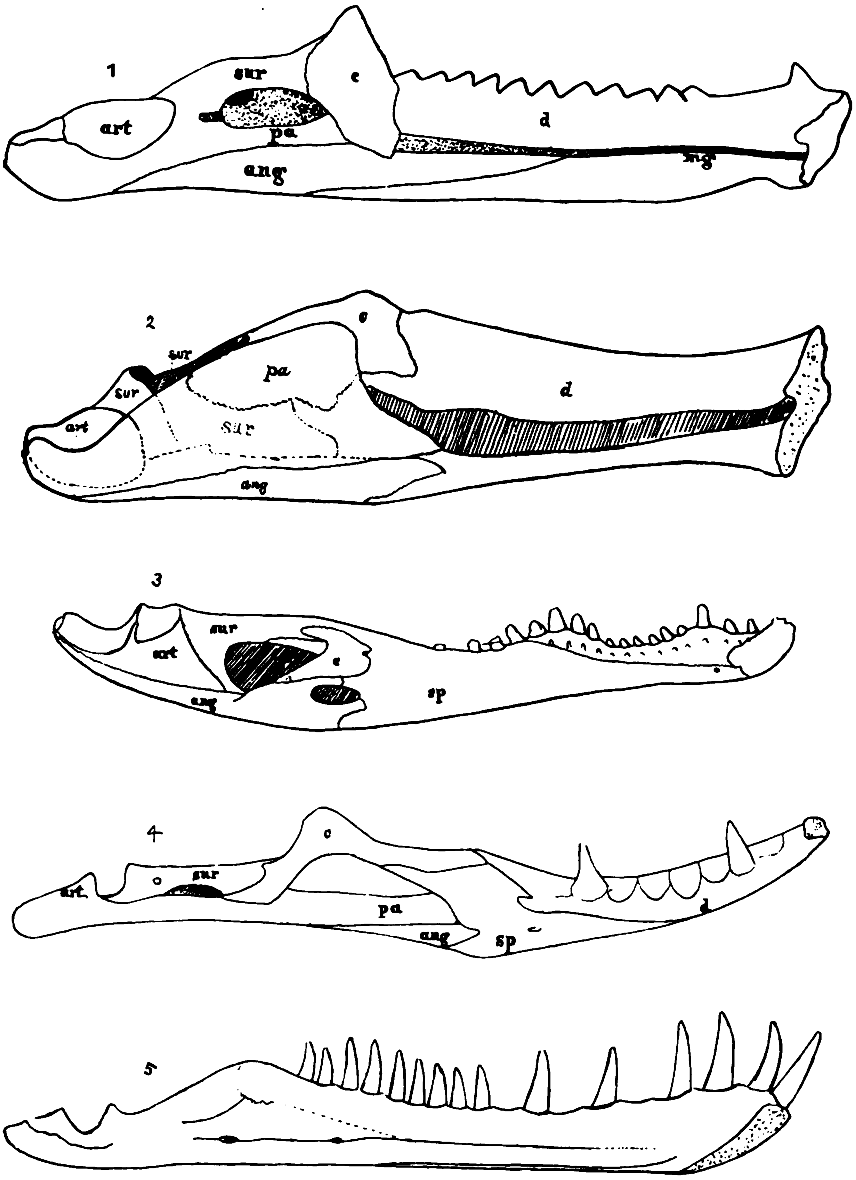
Fig. 2, *Chelydra.*

Fig. 3, *Alligator.*

Fig. 4, *Varanus.*

Fig. 5, *Cimoliasaurus snowii.*

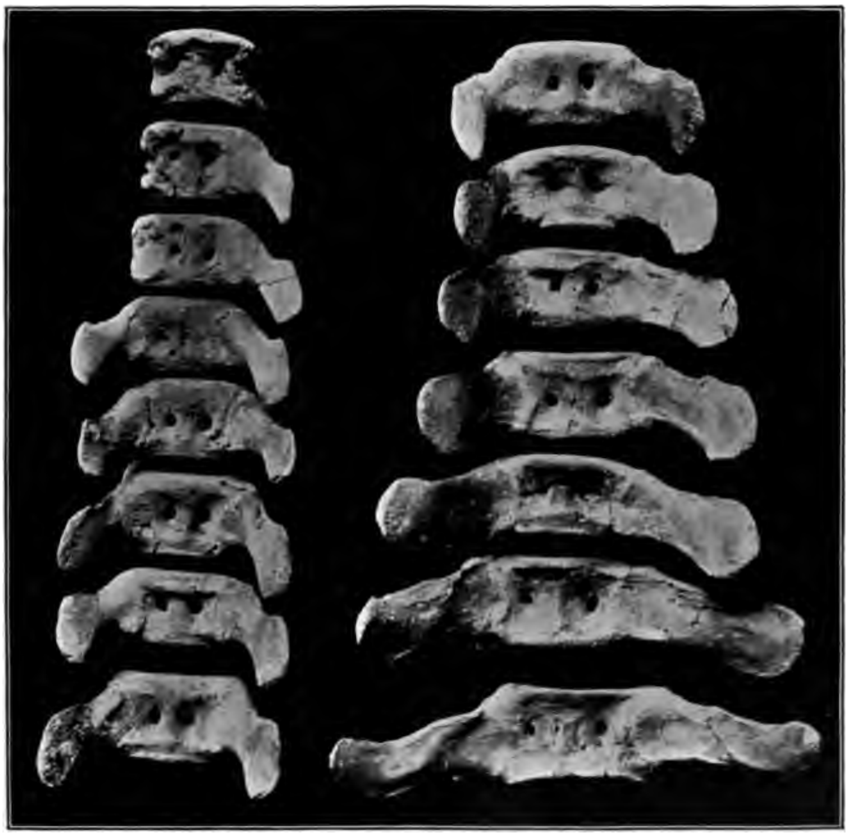
art, articular; *sur,* surangular; *ang,* angular; *c,* coronoid; *pa,* prearticular; *sp,* splenial; *d,* dentary; *mg,* Meckel's groove.



INNER SIDE OF THE LEFT MANDIBLE OF VARIOUS REPTILES.

PLATE VI.

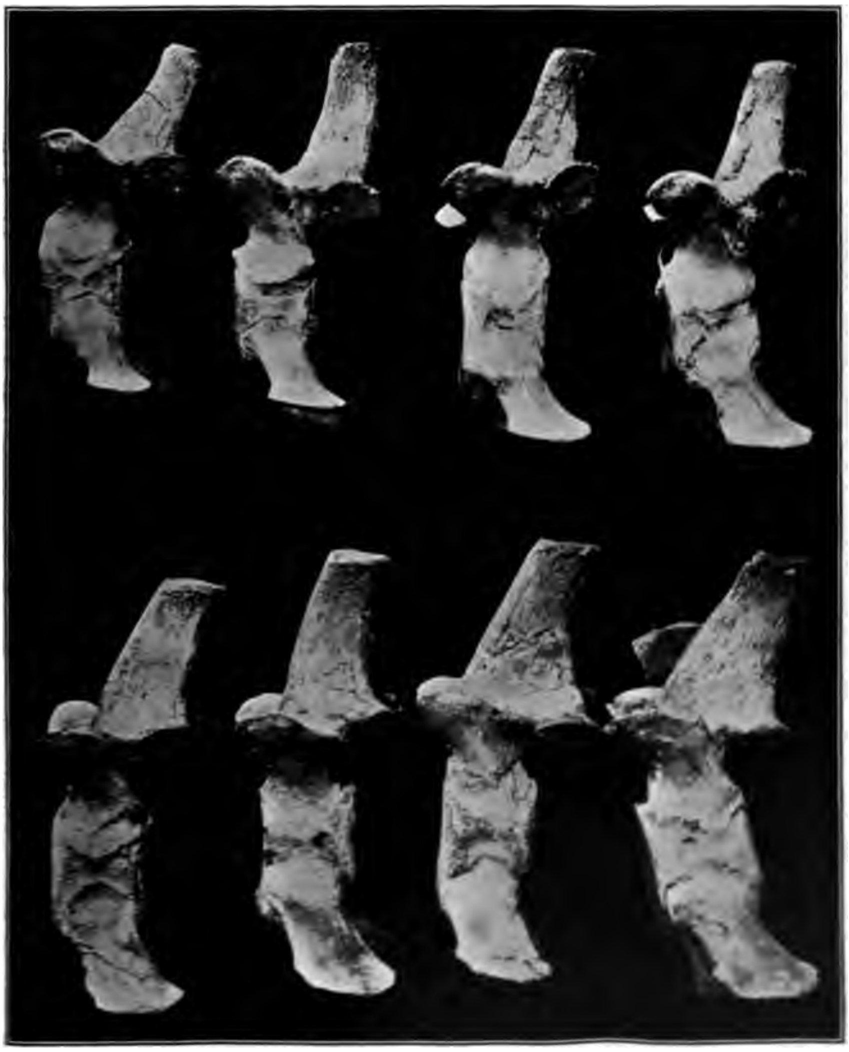
Fourth to eighteenth cervical vertebræ of ***Dolichorhynchops osborni***, from below. ×4/15.



CERVICAL VERTEBRÆ OF DOLICHORHYNCHOPS OSBORNI.

PLATE VII.

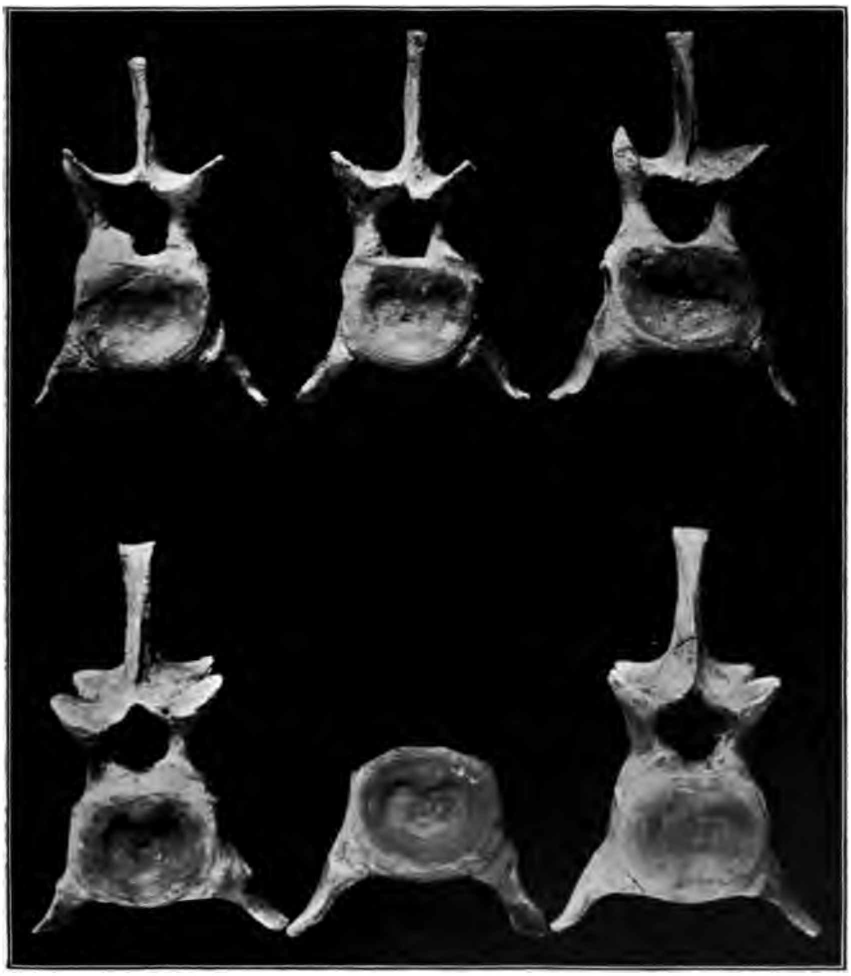
Seventh to fourteenth cervical vertebræ of ***Dolichorhynchops osborni***, from the side. ×4/15.



CERVICAL VERTEBRÆ OF DOLICHORHYNCHOPS OSBORNI.

PLATE VIII.

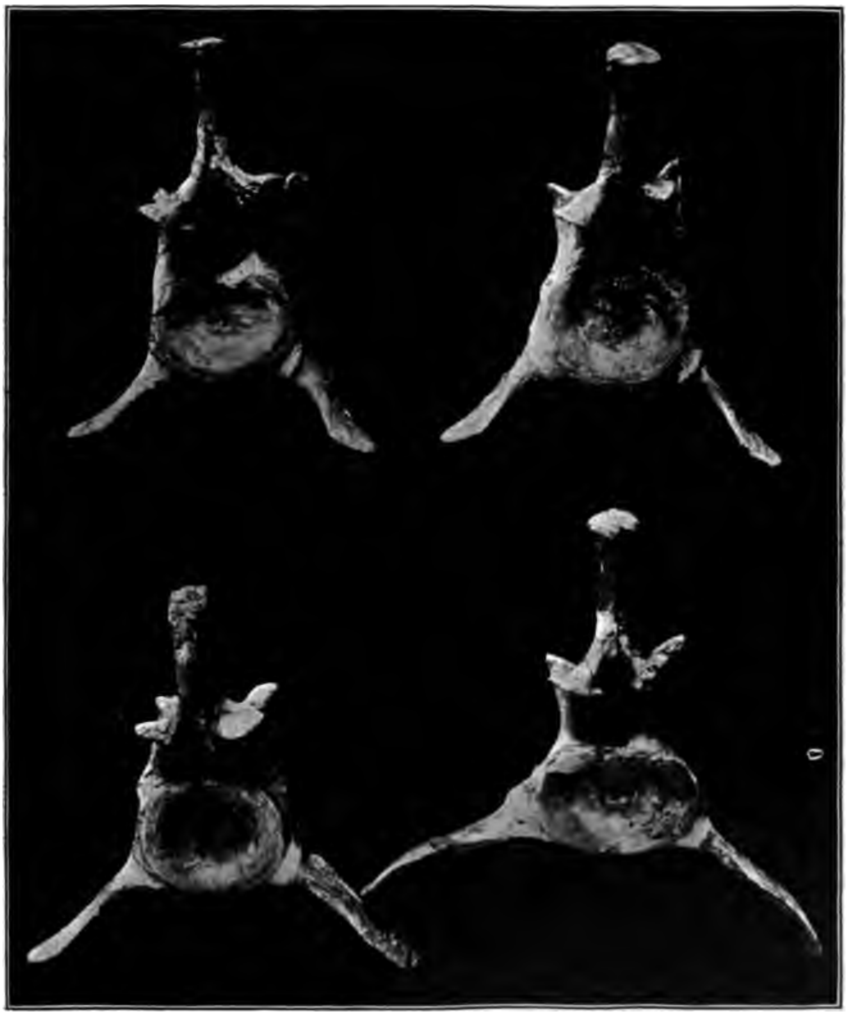
Median cervical vertebræ of ***Dolichorhynchops osborni***, from the front. ×4/15.



Cervical Vertebræ of Dolichorhynchops osborni.

PLATE IX.

Posterior cervical vertebræ of *Dolichorhynchops osborni*, from behind. 4/15.

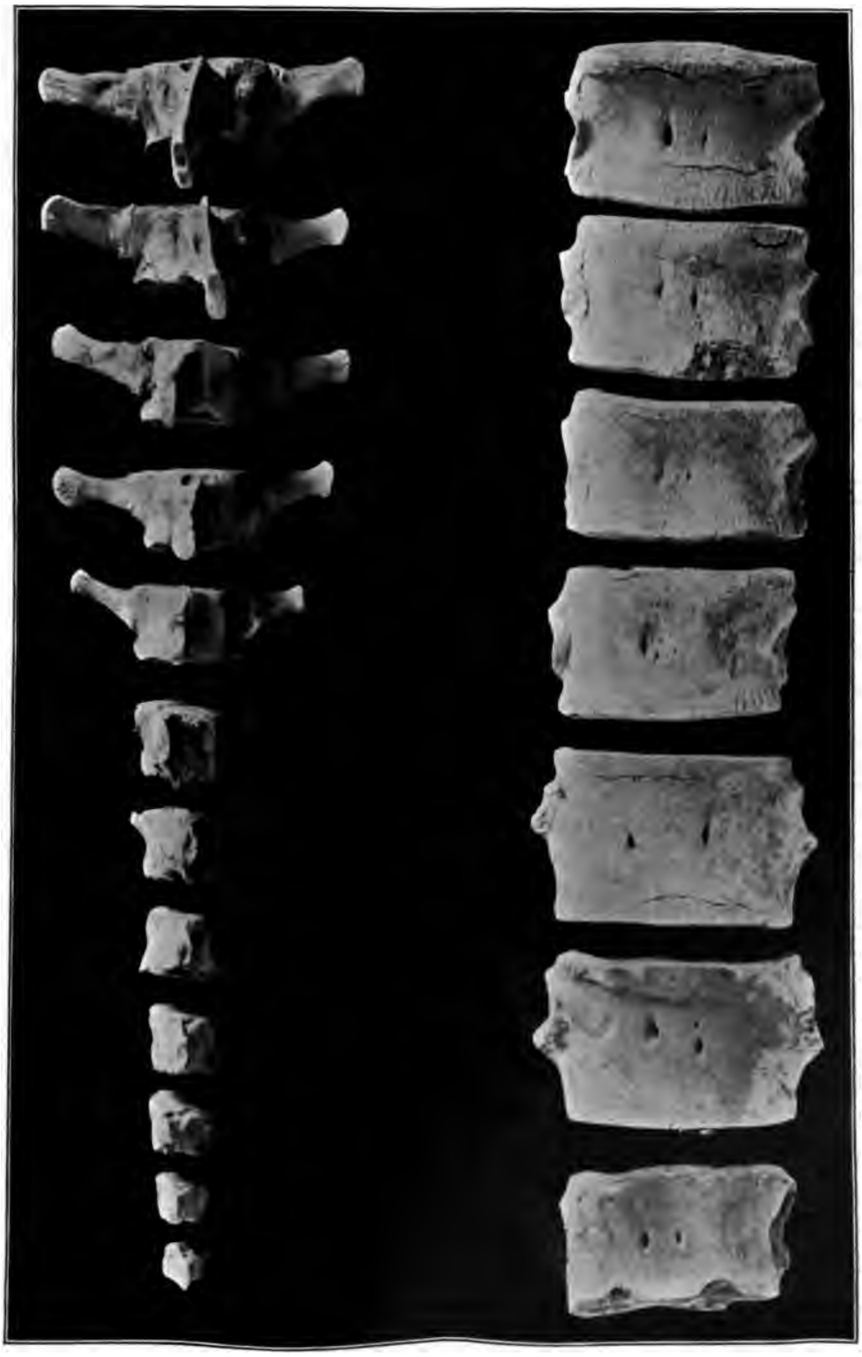


CERVICAL VERTEBRÆ OF DOLICHORHYNCHOPS OSBORNI.

PLATE X.

Left series, distal caudal vertebræ of *Dolichorhynchops osborni*, from above. ×11/24.

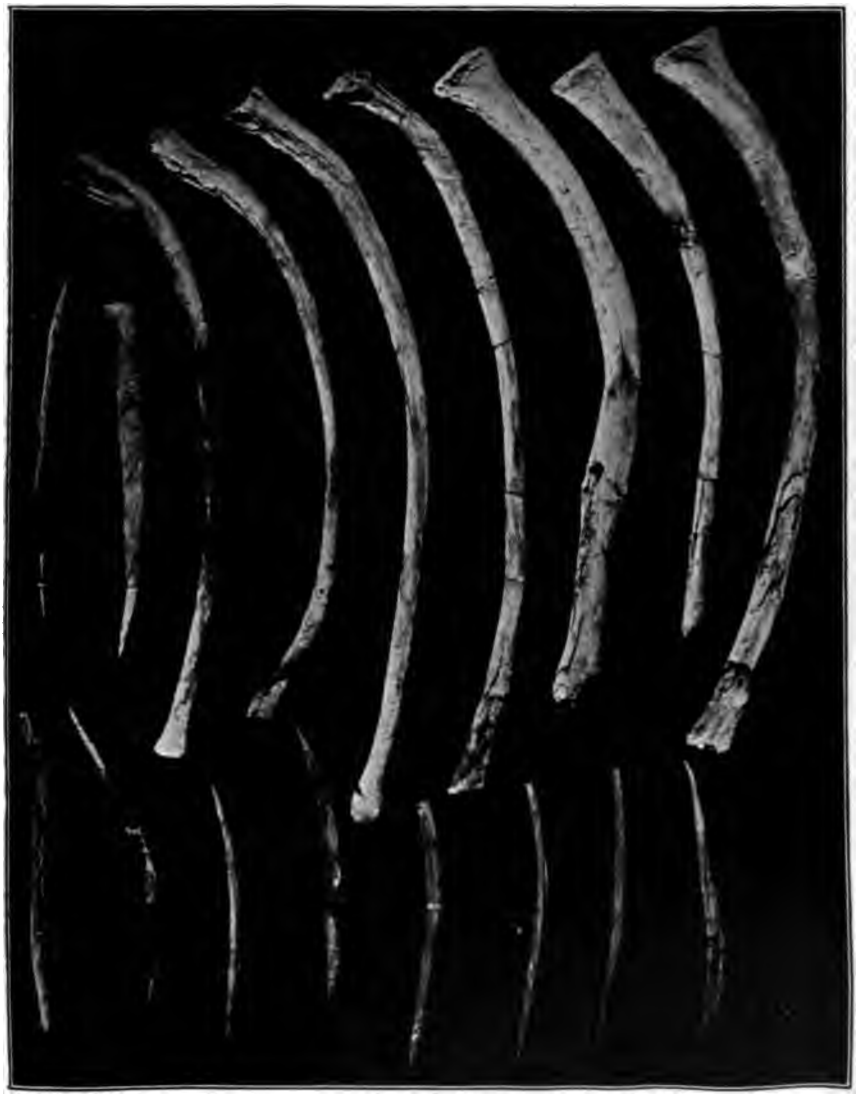
Right series, cervical vertebræ of *Polycotylus ischiadicus*, from below. ×11/24.



LEFT SERIES, CAUDAL VERTEBRÆ OF DOLICHORHYNCHOPS OSBORNI.
RIGHT SERIES, CERVICAL VERTEBRÆ OF POLYCOTYLUS ISCHIADICUS.

PLATE XI.

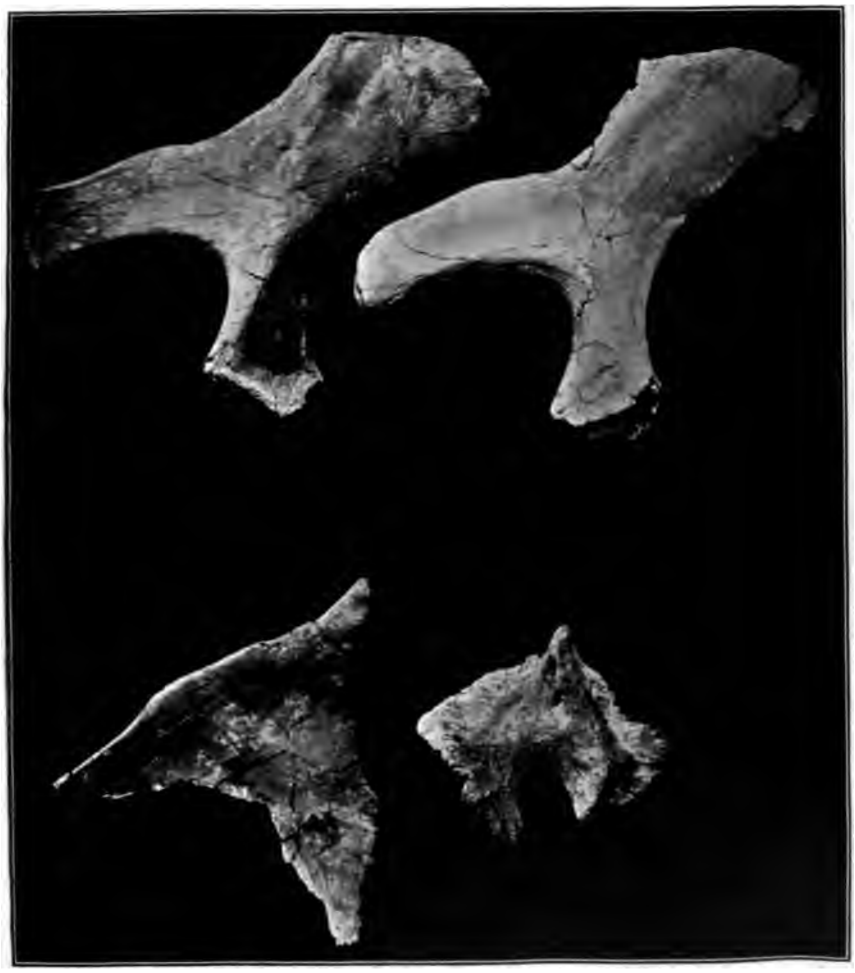
Thoracic and abdominal ribs of *Dolichorhynchops osborni*. × 1/3.



Ribs of Dolichorhynchops osborni.

PLATE XII.

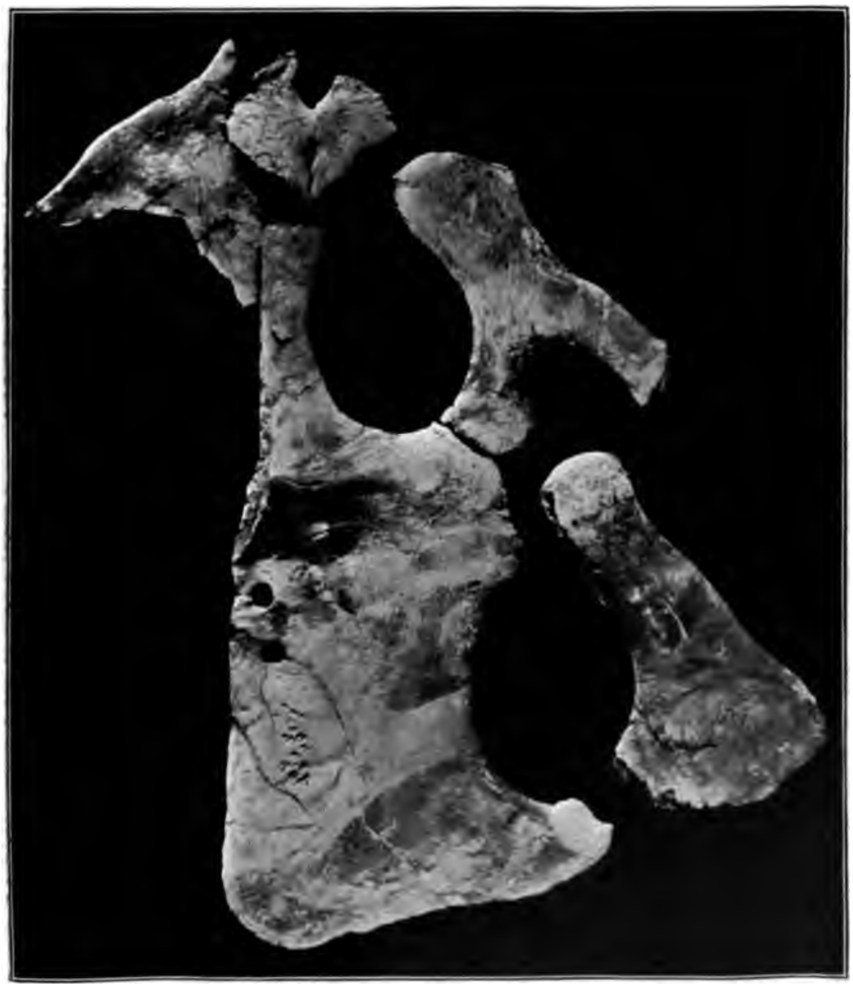
Bones of pectoral girdle of *Dolichorhynchops osborni*. ×7/13.
Upper left figure, right scapula, from without.
Upper right figure, left scapula, from within.
Lower left figure, left clavicle, from above.
Lower right figure, episternum, from below.



BONES OF PECTORAL GIRDLE OF DOLICHORHYNCHOPS OSBORNI.

PLATE XIII.

Bones of pectoral girdle of *Dolichorhynchops osborni*, from above. ×3/14.
Upper left figure, left clavicle.
Upper middle figure, episternum.
Upper right figure, scapula.
Lower left figure, right coracoid.
Lower right figure, humerus.



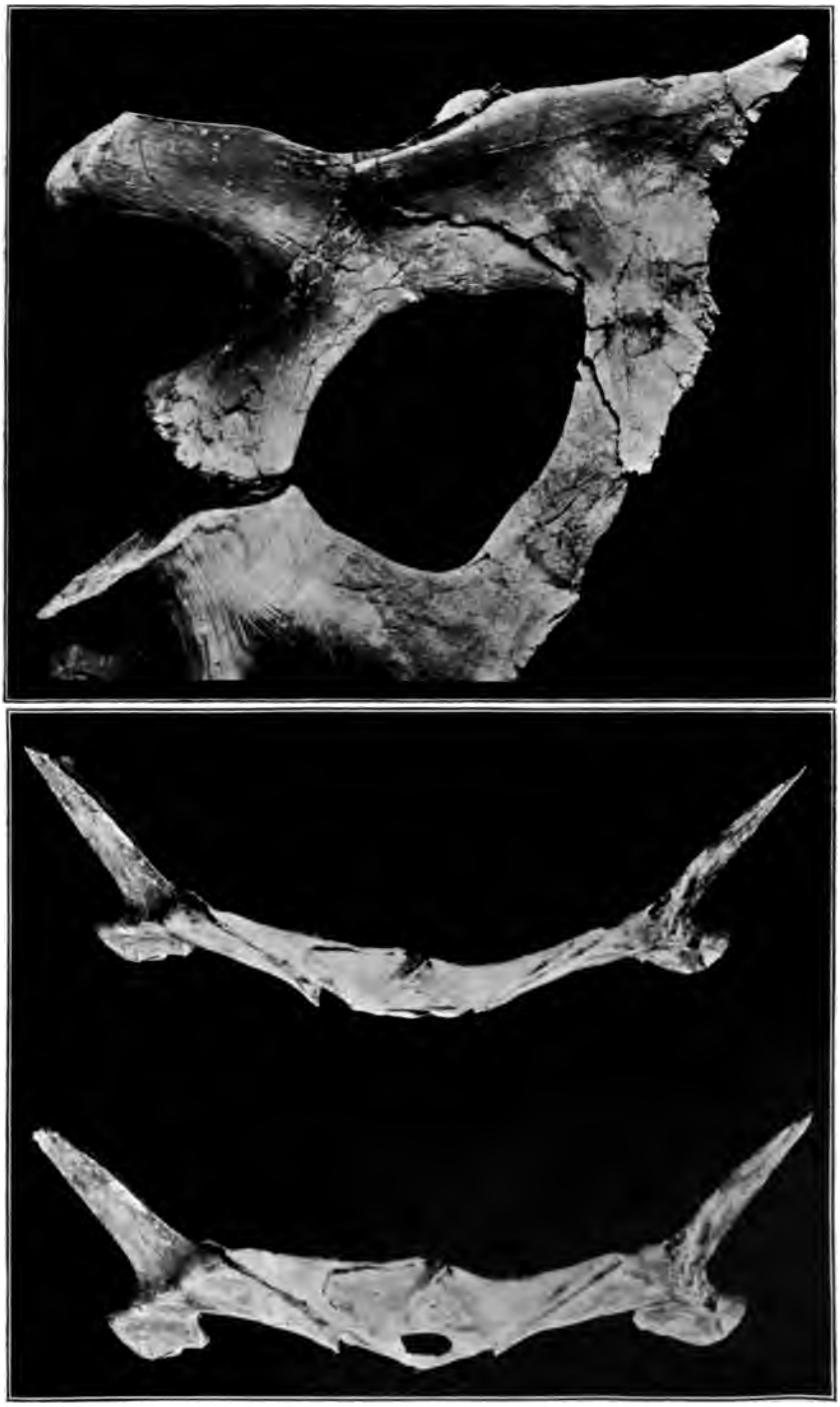
Pectoral Girdle of Dolichorhynchops osborni, from Above.

PLATE XIV.

Pectoral girdle of *Dolichorhynchops osborni.*

Upper figure, left clavicle, scapula and upper extremity of coracoid, articulated, from above. ×1/3.

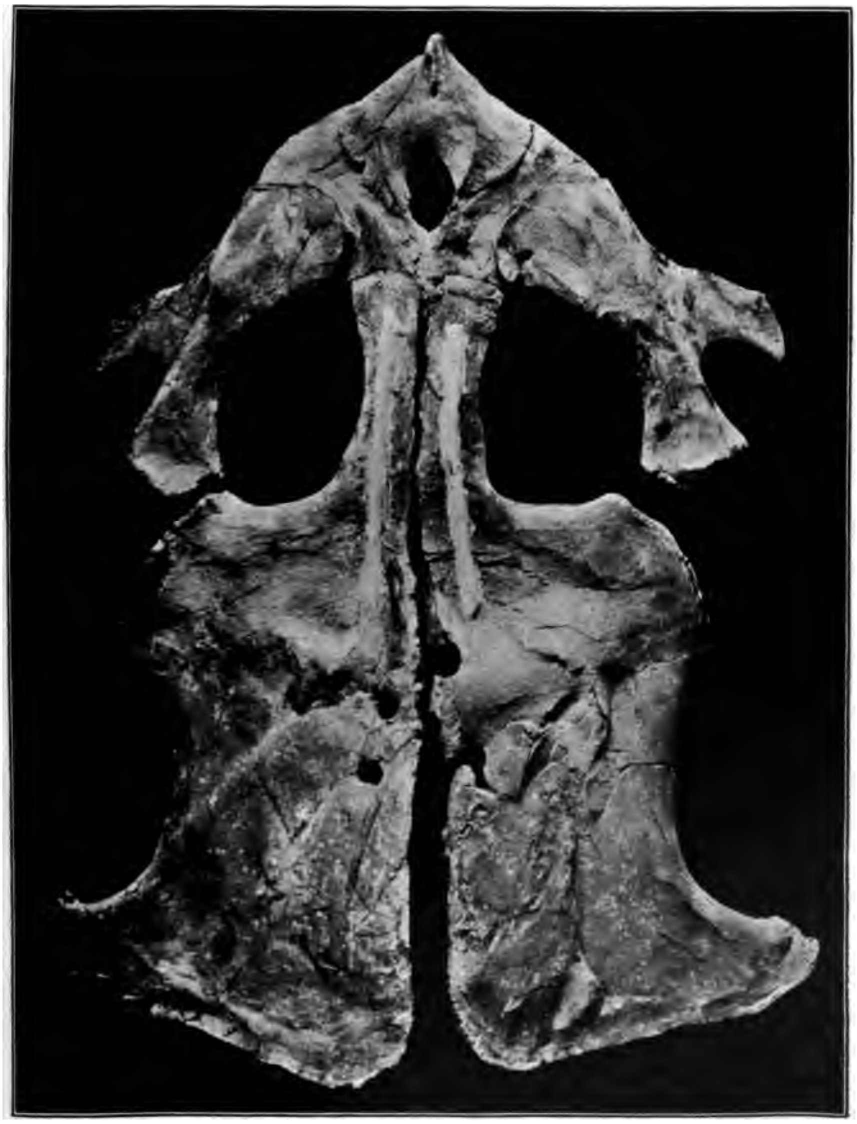
Lower figures, scapulo-clavicular girdle of same, from in front. ×1/4.



PECTORAL GIRDLE OF DOLICHORHYNCHOPS OSBORNI.

PLATE XV.

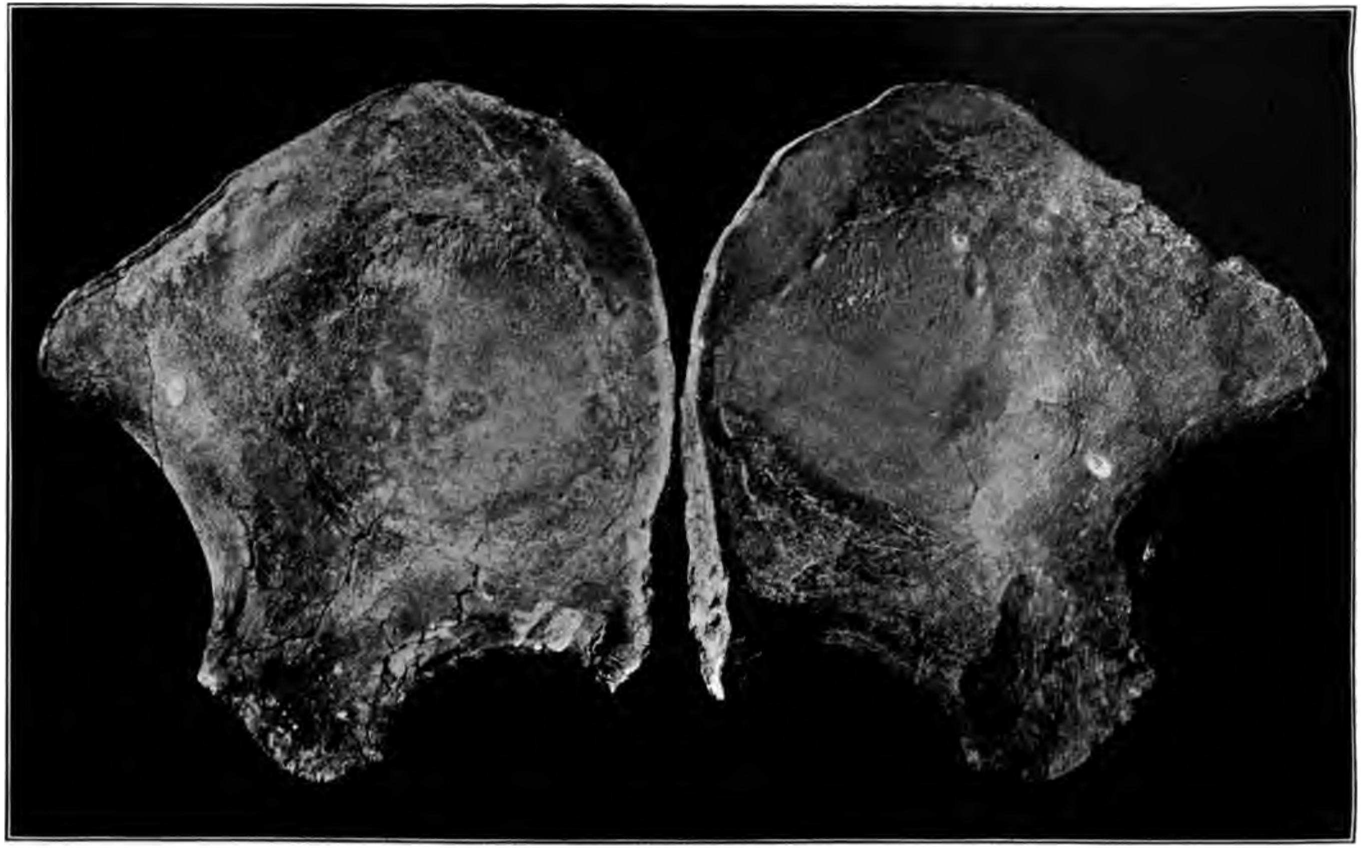
Complete pectoral girdle of *Dolichorhynchops osborni*, **from below, articulated.** ×1/4.



Pectoral Girdle of Dolichorhynchops osborni.

PLATE XVI.

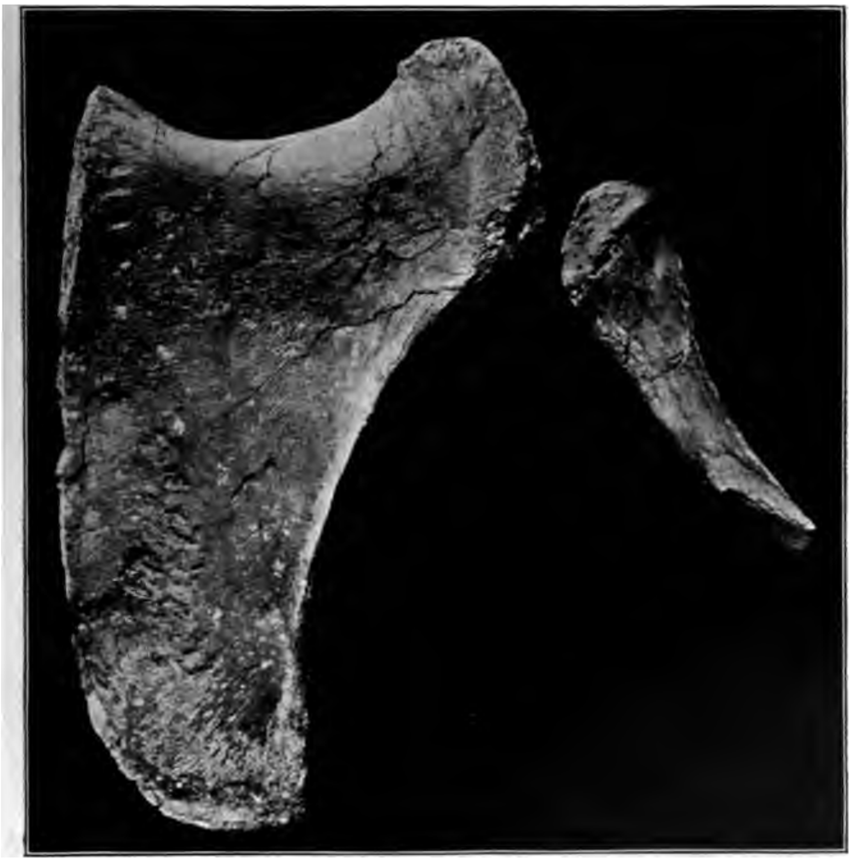
Pubes of *Dolichorhynchops osborni*, from above. ×3/8.



Pubes of Dolichorhynchops osborni.

PLATE XVII.

Right ischium (left figure) and ilium of *Dolichorhynchops osborni*, visceral surface. ×3/8.



ISCHIUM AND ILIUM OF DOLICHORHYNCHOPS OSBORNI.

PLATE XVIII.

Outlines of pectoral and pelvic girdles of different plesiosaurs.

Fig. 1, pectoral girdle of *Cryptoclidus oxoniensis*, after Andrews.

Fig. 2, pelvic girdle of same, after Andrews.

Fig. 3, pelvic girdle of *Cimoliasaurus sp*, from a photograph furnished by Prof. Fraas.

Fig. 4, pelvic girdle of *Cimoliasaurus trochanterius*, after Lydekker.

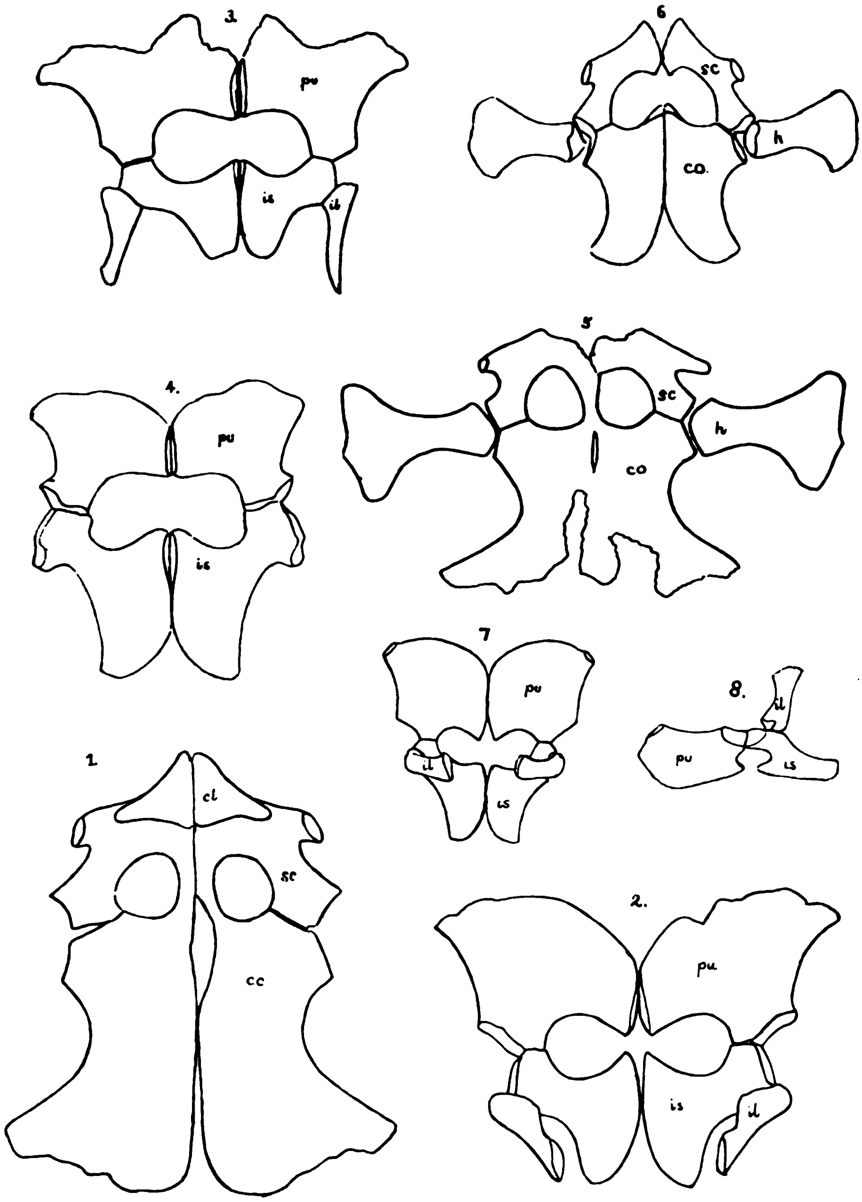
Fig. 5, pectoral girdle of *Plesiosaurus sp*, from photograph from Prof. Fraas.

Fig. 6, pectoral girdle of *Murænosaurus*, after Andrews.

Fig. 7, pelvic girdle of same, after Andrews.

Fig. 8, pelvic girdle of same, from the side, after Andrews.

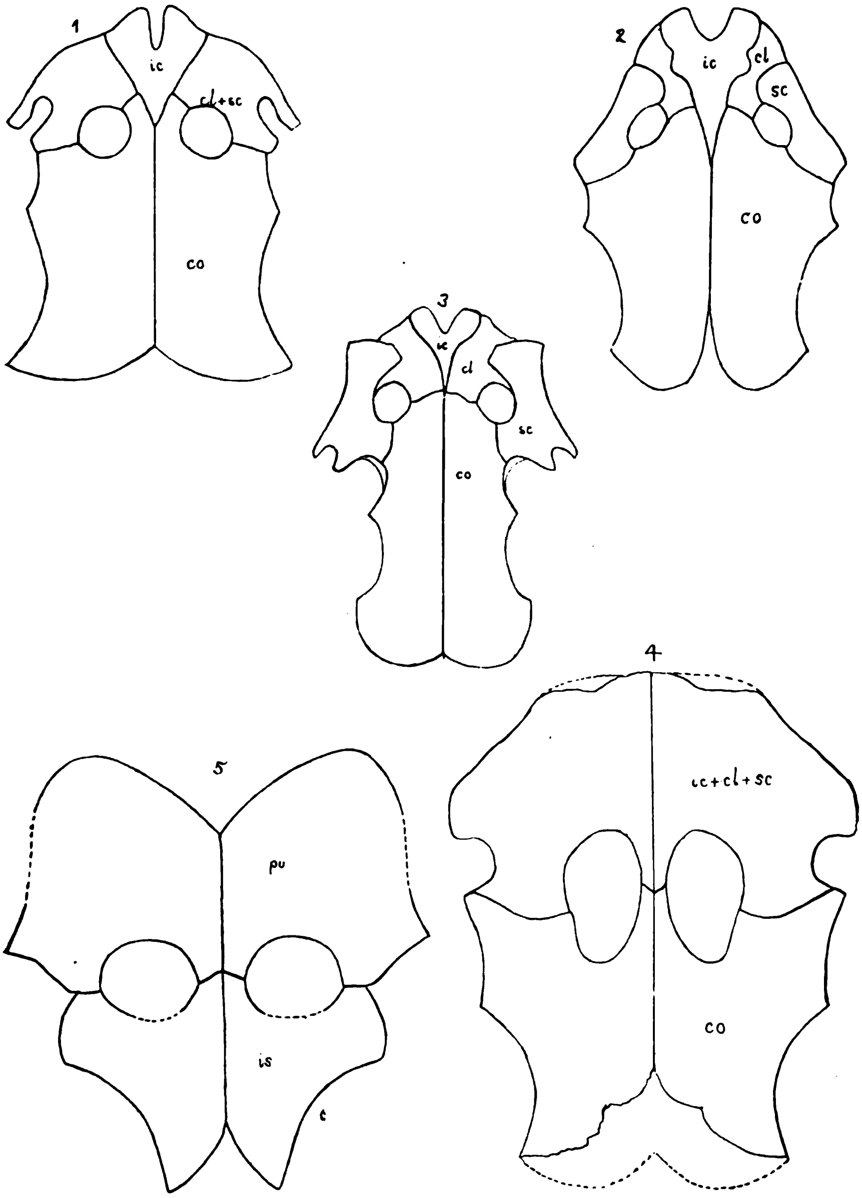
ic, episternum; *cl*, clavicle; *sc*, scapula; *co*, coracoid; *pu*, pubis; *is*, ischium.



Pectoral and Pelvic Girdles of Plesiosaurs.

PLATE XIX.

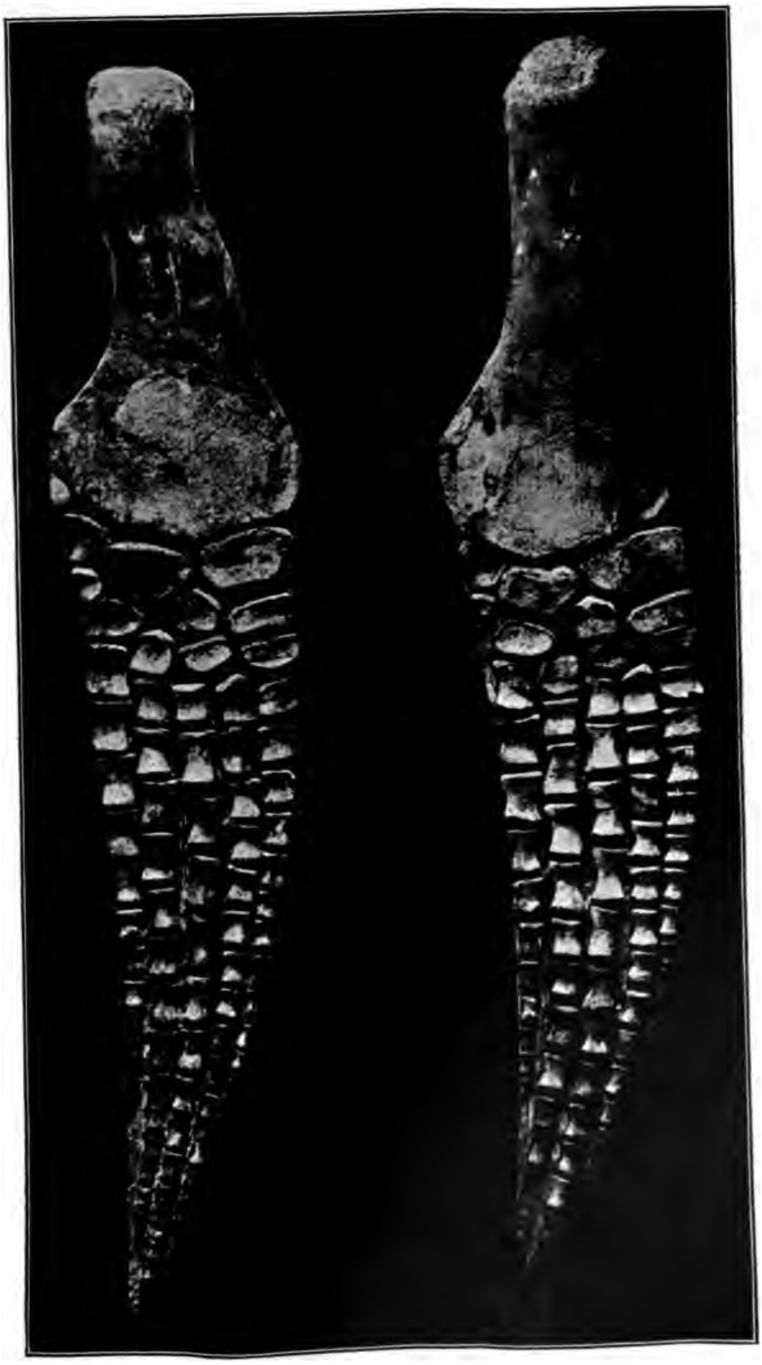
Pectoral and pelvic girdles of plesiosaurs.
Fig. 1, pectoral girdle of *Plesiosaurus*, after Owen.
Fig. 2, pectoral girdle of *Plesiosaurus*, after Woodward.
Fig. 3, pectoral girdle of *Plesiosaurus laticeps*, after Owen.
Fig. 4, pectoral girdle of *Elasmosaurus platyurus*, after Cope.
Fig. 5, pelvic girdle of same, after Cope.
ic, episternum; *cl*, clavicle; *sc*, scapula; *co*, coracoid; *pu*, pubis; *is*, ischium.



PECTORAL AND PELVIC GIRDLES OF PLESIOSAURS.

PLATE XX.

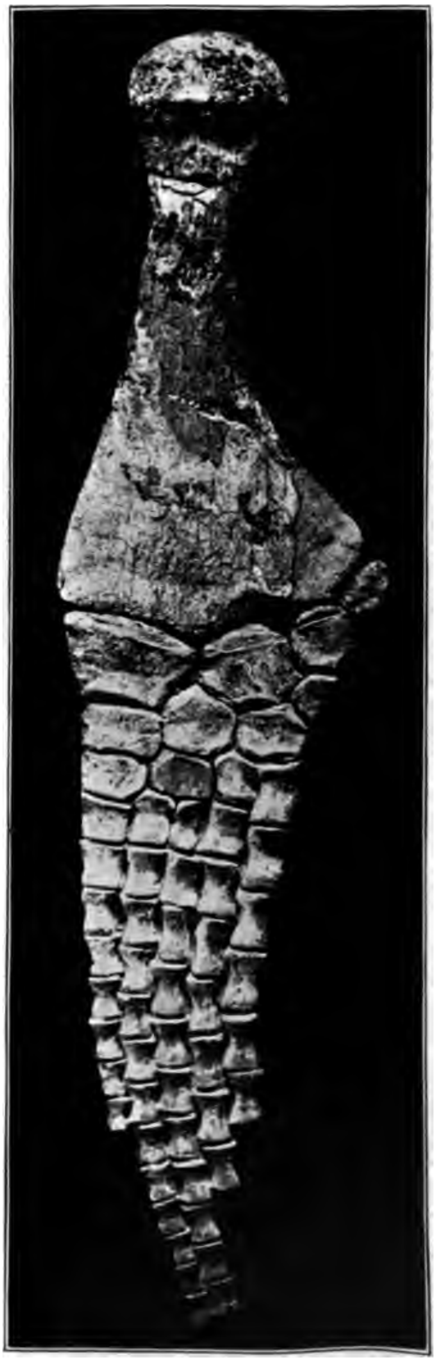
Limbs, as mounted, of *Dolichorhynchops osborni*, dorsal surface. × 1/4.
Left figure, right pectoral paddle.
Right figure, right pelvic paddle.



LIMBS OF DOLICHORHYNCHOPS OSBORNI.

PLATE XXI.

Right pectoral paddle of *Polycotylus latipinnis* Cope, palmar surface. × 1/6.



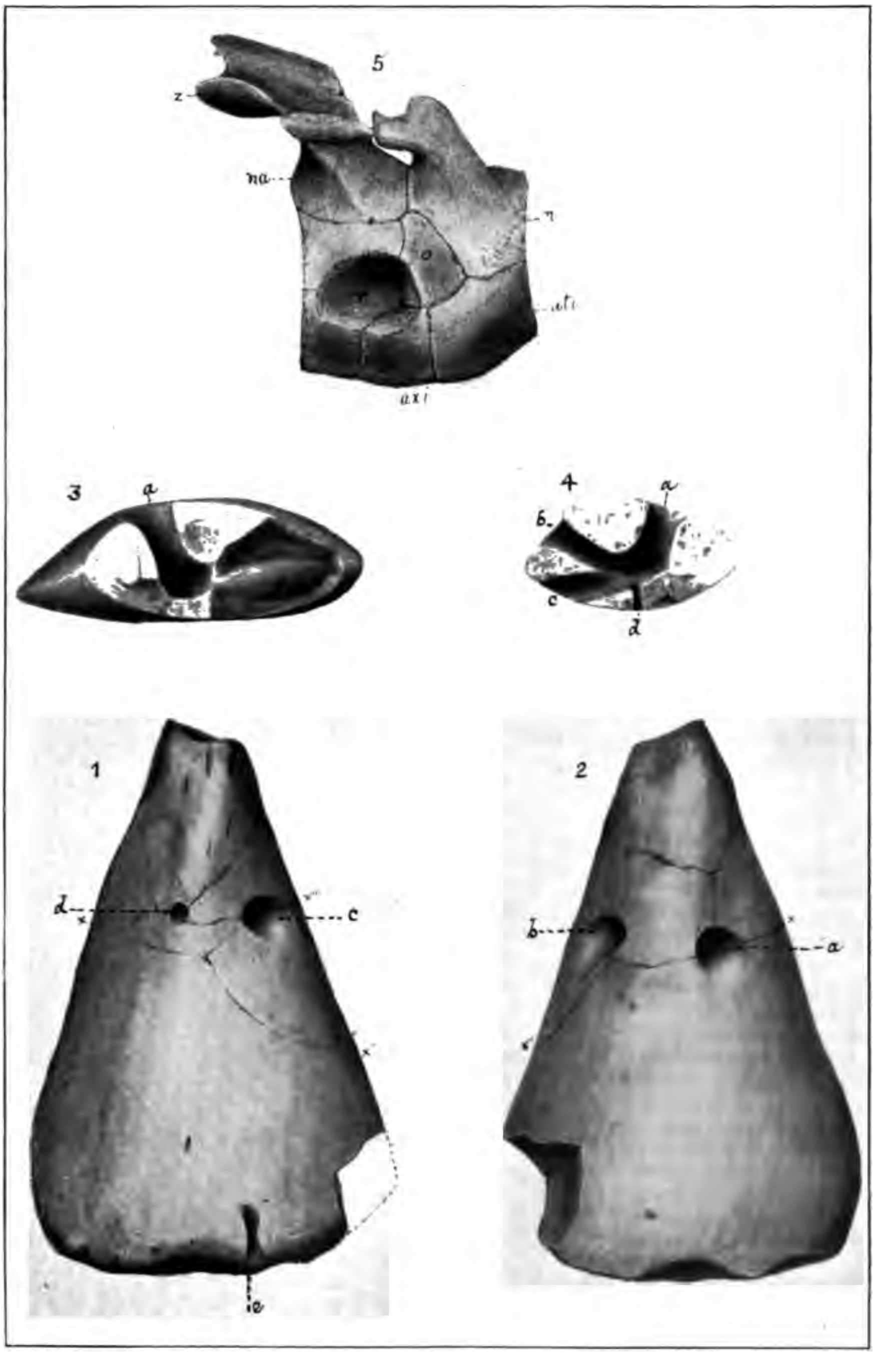
PADDLE OF POLYCOTYLUS LATIPINNIS.

PLATE XXII.

Figs. 1-4, propodial bone of young plesiosaur, from Niobrara Cretaceous. ×3/4.

Fig. 5, atlanto-axis of *Dolichorhynchops osborni*, from the side. ×3/4.

ati, atlantal intercentrum; *axi*, axial intercentrum; *n*, atlantal neurapophysis; *o*, odontoid; *r*, pit for reception of axial rib; *na*, axial neurapophysis; *z*, zygapophysis.



Propodial Bone of Young Pleisosaur. Atlanto-axis of Dolichorhynchops osborni.

PLATE XXIII.

Propodial bones of young plesiosaurs, from the Niobrara Cretaceous of Kansas. × 1/2.

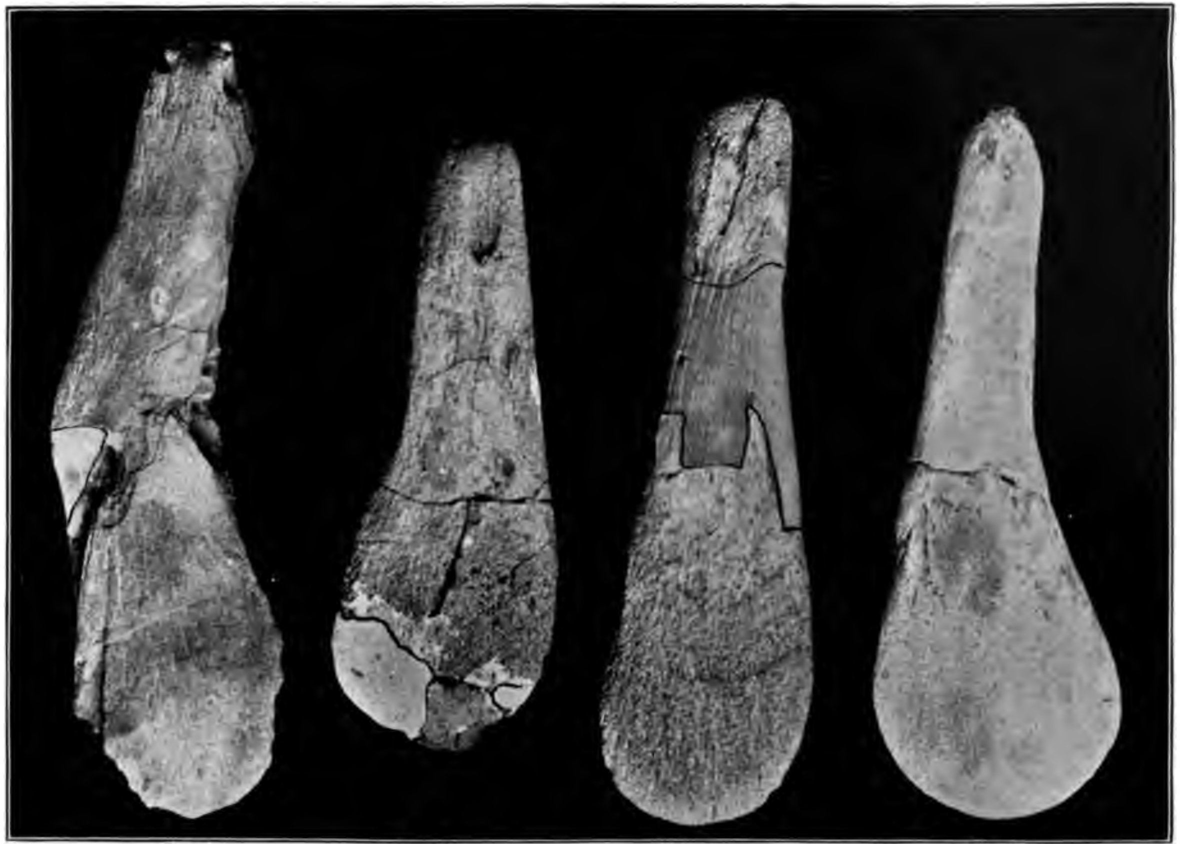


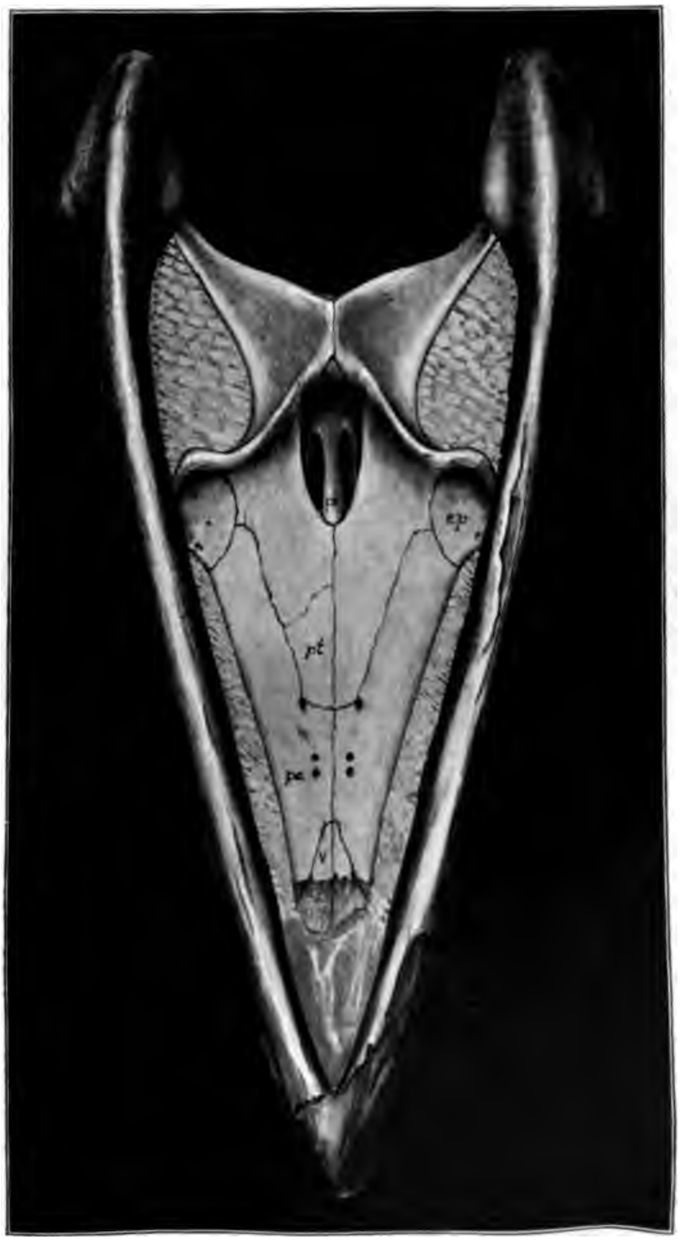
Fig. 1. Fig. 2. Fig. 3. Fig. 4.

PROPODIAL BONES OF YOUNG PLESIOSAURS.

PLATE XXIV.

Palatal view of type specimen of *Brachauchenius lucasi* (redrawn from photograph and sketch). ×3/25.

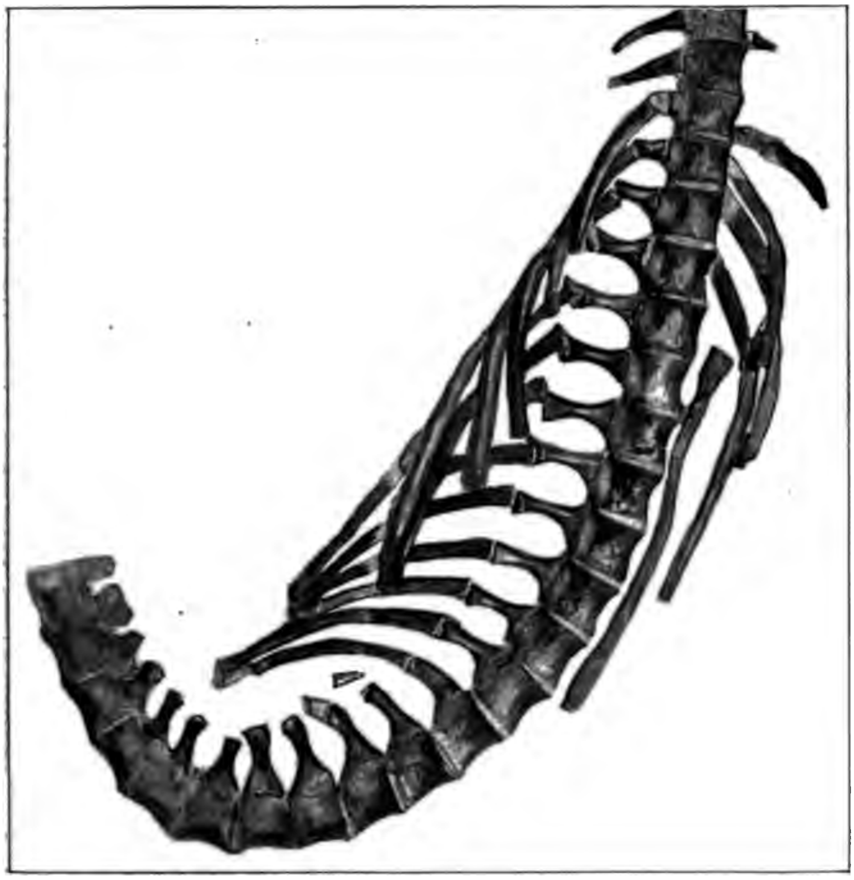
pt, pterygoid; *ep*, ectopterygoid; *pa*, palatine; *ps*, parasphenoid; *v*, vomer; *bs*, basisphenoid.



PALATE OF BRACHAUCHENIUS LUCASI.

PLATE XXV.

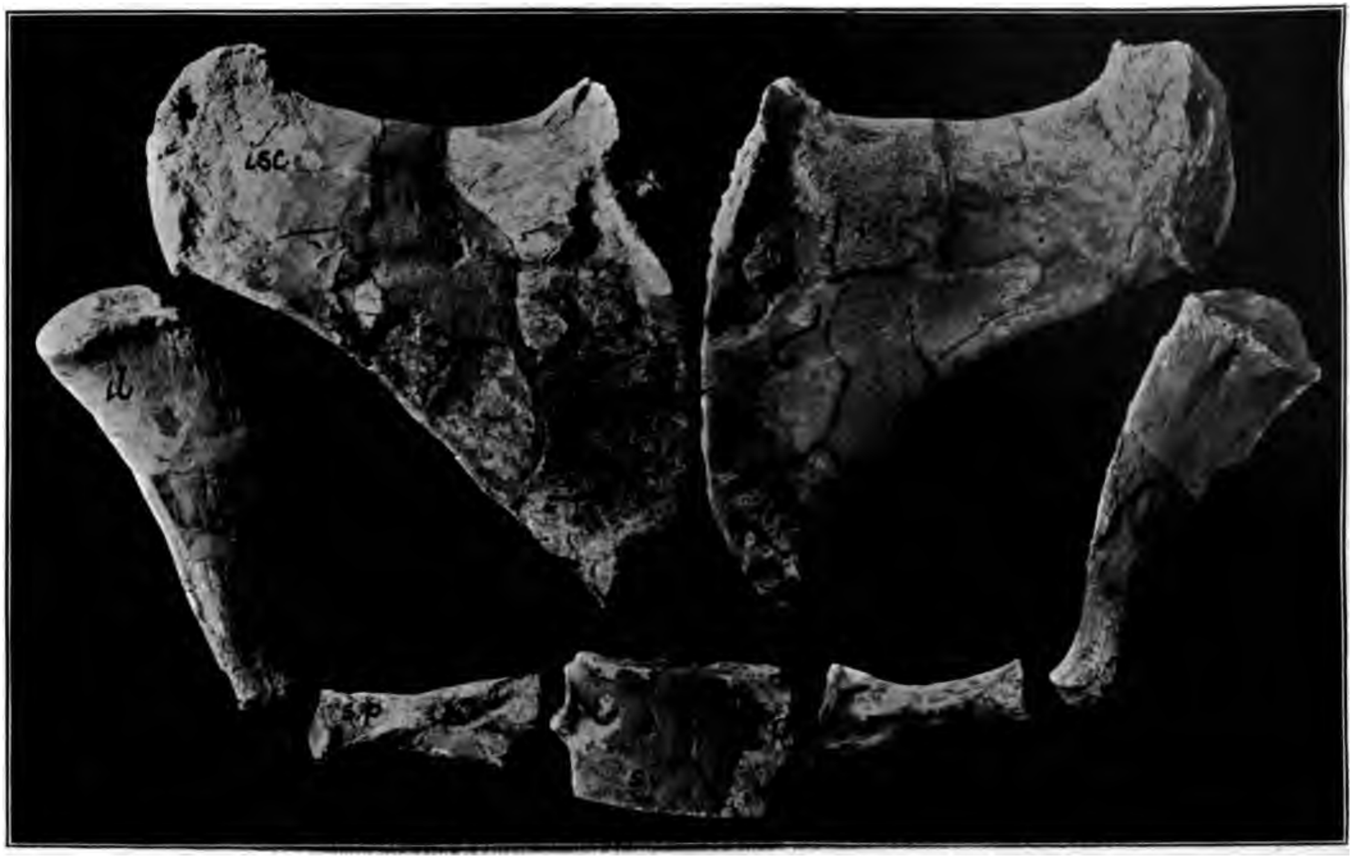
Posterior cervical and dorsal vertebræ, and ribs of *Brachauchenius lucasi*, from below. ×1/10.



VERTEBRÆ AND RIBS OF BRACHAUCHENIUS LUCASI.

PLATE XXVI.

Pelvic bones of *Polycotylus ischiadicus* Willist., visceral surface. ×1/3.
is, ischium; *il*, ilium; *sp*, sacral rib; *sv*, sacral vertebra.



Pelvic Bones of Polycotylus ischiadicus.

PLATE XXVII.

Fig. 1, episternum and portion of clavicles of *Plesiosaurus mudgei* (?) Cragin, from below. × 1/2.

Fig. 2, dorsal vertebra of *Plesiosaurus gouldii* (type specimen), from the front. × 1/2.

Fig. 3, the same, from the side. × 1/2.

Drawn by Sidney Prentice.

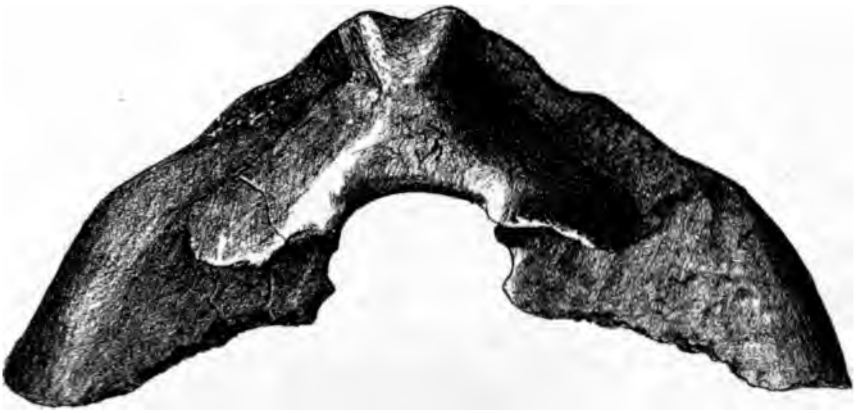


Fig. 1.

EPISTERNUM AND PORTION OF CLAVICLES OF PLESIOSAURUS MUDGEI.

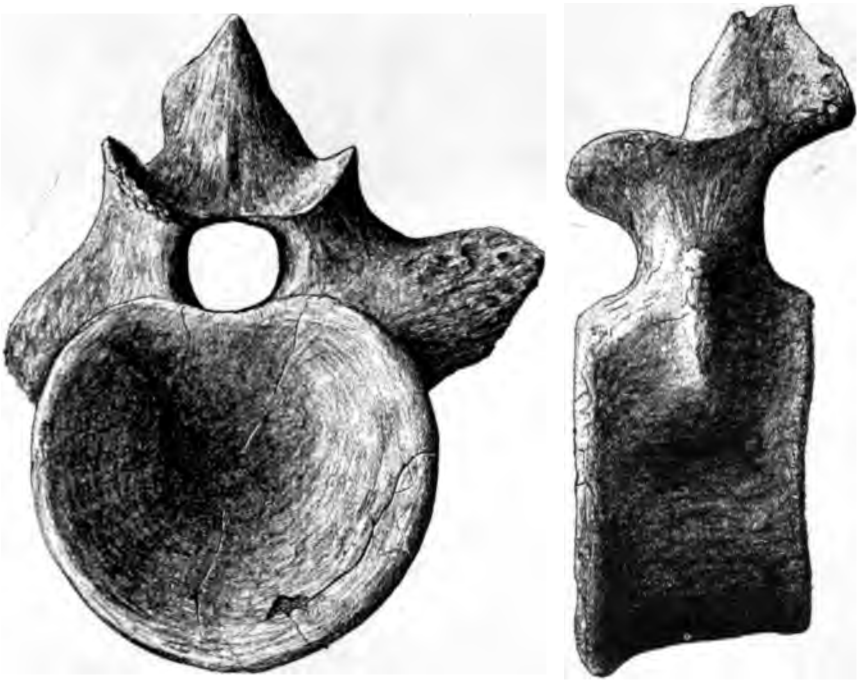
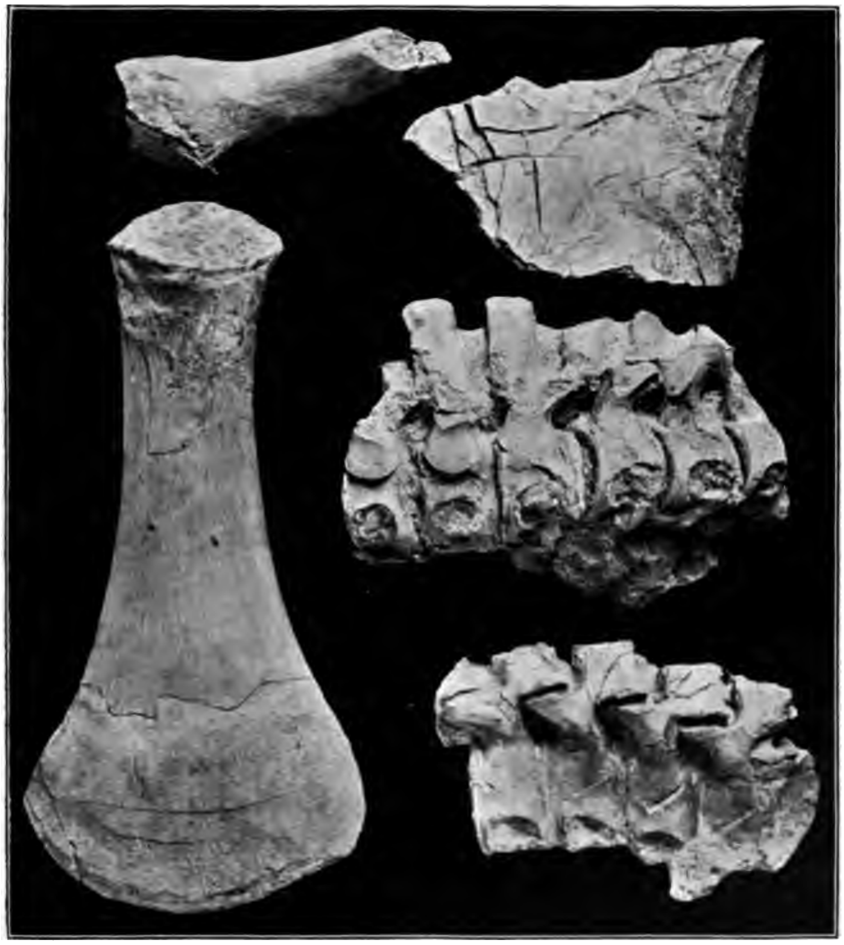


Fig. 2. Fig. 3.

DORSAL VERTEBRA OF PLESIOSAURUS GOULDII.

PLATE XXVIII.

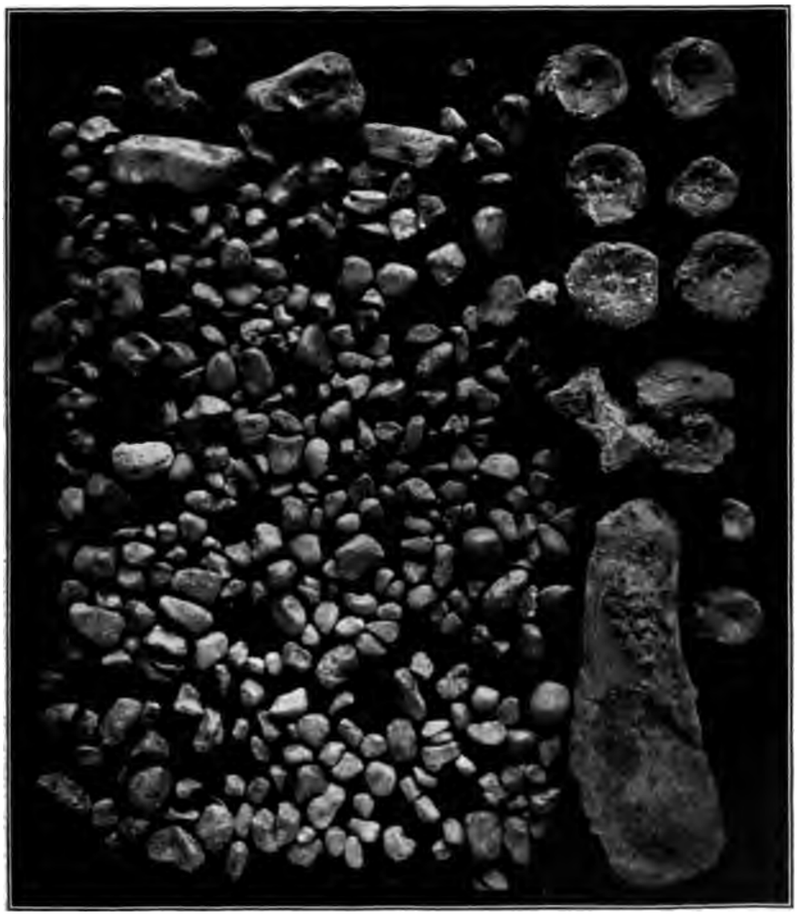
Trinacromerum anonymum Willist. ×3/11.
Upper figures, parts of ilium and coracoid.
Lower figures, humerus, as restored, and cervical vertebræ.



TRINACROMERUM ANONYMUM.

PLATE XXIX.

"Stomach pebbles," vertebræ and femur of ***Plesiosaurus mudgei*** **Cragin, reduced.**



"STOMACH PEBBLES" OF PLESIOSAUR.

FIELD COLUMBIAN MUSEUM
PUBLICATION 77
GEOLOGICAL SERIES VOL. II, NO. 2

CATALOGUE
OF THE
COLLECTION OF METEORITES
MAY 1, 1903

BY

OLIVER CUMMINGS FARRINGTON, PH.D.
Curator, Department of Geology

CHICAGO, U. S. A.
May 15, 1903

CATALOGUE OF THE COLLECTION OF METEORITES, MAY 1, 1903.

BY

OLIVER CUMMINGS FARRINGTON.

INTRODUCTION.

Since the first catalogue of the meteorite collection was issued* over seventy falls have been added and a number of other changes made.

It has, therefore, seemed desirable to prepare a second catalogue, not only to record the growth of the collection, but also to contribute new data to the subject of meteorites in general.

The following table shows the additions to the collection:

	July 15, 1895.	May 1, 1903.
Number of falls represented	179	251
Total weight	2,099 kgs. (4,627 lbs.)	2,289 kgs. (5,048 lbs.)
Number of casts	47	61
Number of micro-sections	5	26

The weight of the collection in 1895, as given above, has been changed from that stated in the first catalogue by the deduction of the Santa Catharina irons, formerly regarded as meteoric.

The following falls have an especially large representation in the collection: Bluff, Brenham, Cañon Diablo, Colfax, Crab Orchard, Farmington, Forest City, Hopewell Mounds, Indian Valley, Kenton County, Long Island, Saline, and Toluca. The weights of these falls possessed by the Museum, as compared with the original weights, are as follows:

	Original Weight.	Weight in Museum Collection.
Bluff	146 kgs.	13.9 kgs.
Brenham	900 "	445 "
Cañon Diablo	Indeterminate. At least 4,000 "	689.8 "
Colfax	2.4 "	1.2 "
Crab Orchard	43 "	12.2 "
Farmington	84 "	23.5 "
Forest City	Indeterminate. At least 122 "	16.5 "
Hopewell Mounds	At least 0.15 "	0.14 "
Indian Valley	14.2 "	8 "
Kenton County	163 "	56.3 "
Long Island	At least 564 "	528 "
Saline	31.13 "	20.5 "
Toluca	Indeterminate. At least 1,000 "	177 "

---

* Handbook and Catalogue of the Meteorite Collection, Field Col. Mus. Pub. 3, Geol. Ser Vol. I, No. 1, Aug. 1895.

The names by which the falls are designated in the catalogue have been chosen with considerable care, and in a few instances depart from previous usage. According to the writer's view, the name by which a meteorite is distinguished should be that of the nearest named locality. The desirability of this in enabling the place of fall or find quickly to be located at any time, without looking up the literature of the fall, can hardly be gainsaid. The exact point of fall or find is a datum of importance, and one whose significance is becoming more and more appreciated. If this datum were in all cases expressed in the name of the meteorite, a vast amount of vexatious labor would be saved to students of meteorites. In the case of the meteorites of the United States, the custom, often traceable to foreign authorities, of calling a meteorite by the name of the county in which it fell or was found is especially to be deprecated. Counties in this country often cover an area of hundreds of square miles. In process of time more than one fall or find is likely to occur within one county, causing a duplication of names if the plan of naming a fall from the county is consistently followed. Another change likely to occur is a subdivision of one county into two or more, thus throwing the place of fall or find out of the county for which it was named. An instance of this is afforded by Auburn, which was originally described from Macon County, but is now in Lee County. Similarly, Ruff's Mountain was formerly in Lexington County, but is now in Newberry County. It is true that in some instances the information regarding a place or find is so indefinite that it can only be designated as within a county, but wherever possible a more definite location should be determined, and the meteorite known by this name, even at the risk of disturbing established usage. That so many American meteorites have continued to be designated by the names of counties has probably been in part due to a lack of appreciation by foreign authorities of the amount of territory included in an American county.

The arrangement of names adopted in the accompanying catalogue is a purely alphabetical one, this being, according to the writer's experience, the most convenient for reference. In the classification of individual meteorites, the systems of Tschermak and Brezina have been followed, with such modifications and new determinations as are due to Wülfing, Cohen, Berwerth, Merrill, and others. The German terms have been put in English form for this catalogue, but the group abbreviations have been retained as in the original. Some falls hitherto without classification have been examined with a view to designation, and the following new determinations made:

Colfax, medium octahedrite, Om.
Hopper (Henry County), medium octahedrite, Om.

Saline, crystalline spherical chondrite, Cck.

Study of the specimens of some falls in the collection has seemed to indicate that their present accepted classification is incorrect, and accordingly the following changes are recommended:

Baratta—Intermediate chondrite, Ci, instead of black chondrite, Cs.

Bridgewater—Medium octahedrite, Om, instead of fine octahedrite, Of.

Indian Valley — Hexahedrite, H, instead of brecciated hexahedrite, Hb.

Lançon—Brecciated gray chondrite, Cgb, instead of white chondrite, Cw.

Tysnes—Brecciated intermediate chondrite, Cib, instead of brecciated gray chondrite.

The additions received to the collection since its inception in 1894 have been obtained by gift, exchange, and purchase. The accessions by gift include a large Cañon Diablo individual, from the Ed. E. Ayer Pioneer Hose Co.; a small individual of the same fall, from George Bell; a small individual of the Estherville fall, from A. E. J. Svege; and sections of the Allegan, Oakley, and St. Genevieve County meteorites, from Prof. H. A. Ward. General G. Murray Guion has kindly continued the loan of the Seneca Falls specimen.

Exchanges conducted with a number of institutions and individuals call for acknowledgment of courtesies from the following:

S. C. H. Bailey, Julius Böhm, Dr. A. Brezina, the British Museum through Prof. L. Fletcher, Prof. E. Cohen, E. E. Howell, Institute of Mines, St. Petersburg, through Prof. Melnikoff, Max Neumann, B. Stürtz, the United States National Museum through Dr. George P. Merrill, the Vienna Museum through Prof. F. Berwerth, Prof. H. A. Ward, Ward's Natural Science Establishment, and the University of Wisconsin through Prof. W. H. Hobbs.

The plates accompanying the catalogue illustrate for the most part specimens obtained subsequent to the publication of the first catalogue. Each will be found described under the corresponding fall in the body of the work.

The clerical work involved in the preparation of the catalogue has been performed with care and accuracy by Mr. Louis V. Kenkel of the Department of Geology.

CATALOGUE OF THE COLLECTION.

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
1	Found 1881.	**Admire,** Lyons Co., Kansas. Iron-stone. Brecciated pallasite, Pb. Two polished sections showing nickel-iron and chrysolite. Structure brecciated. Much oxidized. Cat. No., 557.	59.4
2	Fell 1814, Sept. 5, Noon.	**Agen,** Dep. Lot-et-Garonne, France. Stone. Veined intermediate chondrite, Cia. Fragment from interior, showing white chondri and metallic grains distributed through a darker ground mass. Cat. No., 235.	0.5
		Fragment, with crust. Interior, light-gray with darker spots having the appearance of brecciation rather than of veining; crust, black. Cat. No., 526.	85
3	Fell 1806, Mar. 15, 5 P. M.	**Alais,** Dep. Gard, France. Stone. Carbonaceous chondrite, K. Coarse, brown-black powder resembling an earthy coal. Very friable. Cat. No., 221.	1
		Interior fragment like previous specimen. Cat. No., 222.	0.4
4	Fell 1873.	**Aleppo,** Syria. Stone. Brecciated white chondrite, Cwb. Fragment, with crust. Crust, black, 2 mm. in thickness. Interior, light-gray. Friable. No distinct chondri are visible. Cat. No., 544.	1.45
5	Fell 1883, Feb. 16, 3 P. M.	**Alfianello,** Brescia, Italy. Stone. Intermediate chondrite, Ci. Fragment, with crust. The latter is about .4 mm. in thickness, and of a dirty black color. The interior of the stone is ash-gray, fine-grained, and contains metallic grains, with some coarse nodules of the same. Cat. No., 332.	24
		Interior fragment, ash-gray, with brown spots, due to the oxidation of the metallic particles. Several of the latter are quite large, and rounded as if previously fused. Cat. No., 333.	134.5
		Large fragment, with crust. Characters like those of previous specimen. Cat. No., 334.	300
6	Found 1887.	**Algoma,** Kewaunee Co., Wisconsin. Iron Medium octahedrite, Om. Etched fragment, with crust, well marked Widmanstätten figures, with kamacite uniformly bordered by taenite. Cat. No., 529.	6.5
7	Fell 1899, July 10, 8 A. M.	**Allegan,** Allegan Co., Michigan. Stone. Spherical chondrite, Cc. Fragment, friable, with few metallic grains. Chondri readily separable. Cat. No., 498.	86
		Fragment, with crust. Crust, dirty black, porous. Gift of Prof. H. A. Ward. Cat. No., 500.	56

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
8	Found 1898.	**Arispe,** Sonora, Mexico. Iron. Coarsest octahedrite, Ogg. Etched slab, 12.5 x 10.5 cm., with crust. Shows coarse Widmanstätten figures, and troilite distributed in vein-like manner. There is apparent faulting of the Widmanstätten figures on either side of the vein. Cat. No., 554.	810
9	Found 1894.	**Arlington,** Sibley Co., Minnesota. Iron. Medium octahedrite, Om. Etched fragment, with crust. Shows typical octahedral figures, with the kamacite uniformly bordered by taenite. See Plate XXXII. Cat. No., 459.	70
10	Found 1867.	**Auburn,** Lee Co., Alabama. This locality is usually given as Auburn, Macon Co. This was correct up to 1866, but since that year Auburn has been in Lee Co. Iron. Hexahedrite, H. Sawed fragment showing crust on all surfaces but one. Cat. No., 92.	5
11	Found 1890.	**Augustinowka,** Gov. Ekaterinoslaw, Russia. Iron. Medium octahedrite, Om. Sawed block, with crust. Etched. Shows uniform Widmanstätten figures and veins and inclusions of troilite. Cat. No., 508. Fragment of crust. Much oxidized, and colored green by nickel salts. Cat. No., 507.	217
		Aumale, see Senhadja.	60
12	Fell 1842, June 3.	**Aumieres,** Dep. Lozère, France. Stone. Veined white chondrite, Cwa. Fragment, with crust. Interior light-gray, with minute, shining metallic grains. Rather friable. Individual chondri not discernible. Cat. No., 491.	8.5
13	Fell 1858, Dec. 9, 7:30 A. M.	**Aussun** (Clarac), Dep. Haute Garonne, France. Stone. Spherical chondrite, Cc. Fragment from interior. Light-gray, with rusty-iron grains. Compact. Delicate veins penetrate the mass. Cat. No., 271. Fragment from the interior, with polished surface. The latter shows large chondri of a chrysolite-like mineral, embedded in a ground mass made up chiefly of small white chondri and grains of nickel-iron. Cat. No., 272.	13 22
14	Known 1842.	**Babb's Mill,** Green Co., Tennessee. Iron. Nickel-rich ataxite. Morradal group. Polished slab. Cat. No., 109.	70
15	Fell 1814, Feb. 15, Noon.	**Bachmut** (Alexejewka), Gov. Ekaterinoslaw, Russia. Stone. White chondrite, Cw. Fragment, with crust and polished surface. Crust, dull-black. Interior, light-gray, with a few rusty grains. Cat. No., 234.	12

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
16	Found 1871.	**Bacubirito** (Ranchito), Sinaloa, Mexico. Iron. Finest octahedrite, Off. Thick, etched slab with crust. Very narrow Widmanstätten figures are plainly defined. There are some angular partings and two small troilite inclusions. See Plate XXXV. Cat. No., 537.	352
17	Found 1893.	**Ballinoo,** Australia. Iron. Finest octahedrite, Off. Polished and etched slab with crust. Crust surface smooth and little oxidized, indicating a recent fall. Etched surface shows no figures. Cat. No., 456.	157
18	Fell 1871, Dec. 10, 1:30 P. M.	**Bandong,** Goemoroeh, Java. Stone. Brecciated white chondrite, Cwb. Two fragments from interior. Grayish-brown, with metallic particles. Cat. No., 304.	1.5
19	Fell 1845, May, 5:15 P. M.	**Baratta,** Deniliquin, Australia. Stone. Intermediate chondrite, Ci. Full-sized section, 10 x 15 cm. one surface polished, with crust. Polished surface is thickly sprinkled with gray and white chondri of various sizes. Metallic grains small in size and amount. Many chondri show a rim of metal. Crust thin, black, somewhat rusty. See Plate XXXI. Cat. No., 539.	295
20	Fell 1790, July 24, 9 P. M.	**Barbotan,** Gascony, France. Stone. Gray chondrite, Cg. Fragment from interior, one surface polished, showing numerous, minute, metallic grains. Cat. No., 213. Fragment with crust, showing pitted surface. Much discolored by age. Cat. No., 214.	6 32
21	Fell 1892, Aug. 29, 4 P. M.	**Bath,** Brown Co., South Dakota. Stone. Brecciated spherical chondrite, Ccb. Irregular fragment, with crust and polished surface. The crust surface is indented with broad, shallow pits. Crust, dull-black, papillated, not more than .3 mm. in thickness. Interior, grayish-brown, of fine-granular structure, containing minute metallic grains. A portion shows "slickensided" surface. Cat. No., 351.	1,276
22	Fell 1902, Nov. 15, 6:45 P. M.	**Bath Furnace,** Bath Co., Kentucky. Stone. Intermediate chondrite, Ci. Fragment, with crust and three sawed surfaces. Interior gray, with rusty spots and thickly sprinkled metallic grains. The latter are often irregular in shape and show bronze-yellow inclusions of troilite. The texture of the stone is quite firm. The presence of chondri is indicated by darker and lighter spots. Crust, black and uniform. Shows typical pittings. See Plate XXXII. Cat. No., 555.	366

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
23	Described 1887.	**Beaconsfield,** Victoria Colony, Australia. Iron. Coarse octahedrite, Og. Etched section showing distinct Widmanstätten figures. Contains two troilite nodules each rimmed by schreibersite. Cat. No., 499.	413
24	Found 1866.	**Bear Creek,** Jefferson Co., Colorado. Iron. Fine octahedrite, Of. Fragment showing crust. Octahedral cleavage well displayed. Cat. No., 88.	43.5
		Thin slab, etched. Well marked Widmanstätten figures, the plates of taenite being very distinct. Cat. No., 89.	27
25	Fell 1893, May 26, 3:30 P. M.	**Beaver Creek,** West Kootenai District, British Columbia. Stone. Crystalline spherical chondrite, Cck. Fragment, with crust. Interior, dark-gray, made up of small, glassy chondri, and fine metallic grains. Cat. No., 352.	7
		Like previous specimen. Crust, dull-black, about .3 mm. thick. Cat. No., 353.	19
26	Found 1784.	**Bemdegó,** Bahia, Brazil. Iron. Coarse octahedrite, Og. Scalings from crust, showing magnetite. Cat. No., 3.	
		Slab, 8 x 17 cm., showing natural and etched surfaces. The etched surface exhibits a coarsely crystalline structure with imperfect Widmanstätten figures. Cat. No., 5.	1,132
		Etched slab, 9 x 23 cm., showing imperfect Widmanstätten figures, elongated nodules of troilite and a group of schreibersite inclusions. Cat. No., 6.	855
27	Fell 1798, Dec. 19, 8 P. M.	**Benares,** Bengal, India. Stone. Spherical chondrite, Cc. Powder, showing crust and individual chondri. Cat. No., 216.	.71
		Fragment, with crust. One surface polished, showing scattered metallic grains. Cat. No., 217.	1
28	Fell 1811, July 8, 8 P. M.	**Berlanguillas,** Burgos, Spain. Stone. Veined intermediate chondrite, Cia. Polished fragment. Texture firm. Abundant metallic grains. Cat. No., 492.	5.5
29	Fell 1843, March 25.	**Bishopville,** Sumter Co., South Carolina. Stone. Veined chladnite, Chla. Fragment from interior. Light-gray, with white nodules of the chladnite of Shepard. Rusty brown spots show the presence of metallic grains. Cat. No., 251.	1
		Like previous specimen, but showing vitreous crust. Cat. No., 252.	2
		Fragment of chladnite. Cat. No., 253.	5

Date ll or Find.	NAME AND DESCRIPTION.	Weight in grams.
ınd 1802.	**Bitburg** (Albacher Mühle), Rhenish Prussia.	
	Iron-stone. Pallasite P. Polished slab showing large pores and slag-like surface, due to its having been passed through a furnace. Cat., No., 30.	22
	Fragment, three sides polished. The natural surface appears to be altering to limonite. Cat. No., 31.	72
1887, l.	**Bjelokrynitschie,** Volhynia, Russia.	
	Stone. Brecciated intermediate chondrite, Cib. Polished fragment with crust. Mottled gray and brown, groundmass with numerous metallic grains of irregular size. Compact in texture. Crust black, firmly adhering. Cat. No., 484.	9
1899, :h 12, P. M.	**Bjürböle,** near Borgo, Finland.	
	Stone. Spherical chondrite, Cc. Fragment with crust. Stone friable, and chondri of the size of peas and smaller, are easily separable. There are angular inclusions of a homogeneous, fine-grained rock also. The crust is black, coarse, and shows in places lines of flow. Metallic grains scarce. See Plate XXXII. Cat. No., 522.	310
ıd 1878.	**Bluff,** Fayette Co., Texas.	
	Stone. Brecciated crystalline chondrite, Ckb. About one-tenth the original mass, showing crust and polished surface 25 x 35 cm. The crust surface is somewhat decomposed, but shows the characteristic pittings. The polished surface shows the dark-green color of the stone, with its fine texture and scattered metallic grains. Cat. No., 173.	10,985
	Thin slab 31 x 38 cm., exhibiting the black veins peculiar to this meteorite. Cat. No., 174.	2,934
ıd 1829.	**Bohumilitz,** Bohemia, Austria.	
	Iron. Coarse octahedrite, Og. Etched slab, 6.5 x 9 cm. with crust. Shows typical swollen octahedral figures. Cat. No., 487.	275
1852, 13, M.	**Borkut,** Marmaros, Hungary.	
	Stone. Spherical chondrite, Cc. Fragments showing individual chondri, spheroidal, dark-green in color. Cat. No., 262.	.12
1847, 14, A. M.	**Braunau,** Hauptmannsdorf, Bohemia.	
	Iron. Hexahedrite, H. Sawed block showing natural surface with pits. The luster of the natural surface is like that of blued steel. Cat. No., 55.	47
	Brazos River, see Wichita Co.	

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
37	Fell 1855, May 13, 5 P. M.	**Bremervörde,** (Gnarrenburg), Prov. Hanover, Germany.	
		Stone. Brecciated spherical chondrite, Ccb. Fragment from interior. Cat. No. 265.	.5
		Fragment with crust, and polished surface. The polished surface is gray, mottled with white chondri and irregular metallic grains, some of them large. Crust black, thin. Cat. No., 438.	72
38	Found 1882.	**Brenham,** Brenham Township, Kiowa Co., Kansas.	
		Iron-stone. Pallasite, P.	
		One-half of a complete individual, one surface polished. Composed chiefly of iron, with chrysolite filling the sponge-like pores. Cat. No., 195.	2,061
		Thin slab, polished. The central portion for a width of about 5 cm. is solid metal, but on either side the mass is porous, the pores being filled with chrysolite. Cat. No., 196.	1,248
		Full-sized slab, polished, showing a sponge-like mass of iron, with chrysolite filling the cavities. Cat. No., 197.	2,048
		Similar to No. 197, but thicker. Some of the chrysolite nodules are beautifully transparent and highly refracting. Cat. No., 198.	8,117
		Smaller piece, similar to No. 197. Cat. No., 199.	227
		466 pound mass, entire. The form is flattened, somewhat heart-shaped. The surface is covered with pittings, and considerably oxidized. The grains of chrysolite are readily discernible over the surface. Cat. No., 200.	218,847
		Full-sized slab, showing structure like No. 197. Cat. No., 201.	5,895
		18 pound mass, entire. Form, hemispheroidal, the surface covered with pittings. Structure porous, pores filled with chrysolite. Cat. No., 202.	8,619
		Section of complete individual, showing natural and polished surface. The structure is like that of No. 197. Cat. No., 203.	8,490
		345 pound mass, entire. This is almost wholly iron. Form, kidney or arch-shaped, with a projection extending from the concavity of the arch. Cat. No., 204.	155,473
		36 pound mass, entire. Spheroidal in form, surface covered with pittings. Entirely metallic. Cat. No., 205.	16,091
		40 pound mass, entire. Form, cylindrical, with one projecting point. Surface pitted. Composed almost wholly of iron, but occasional grains of chrysolite are visible. Cat. No., 206.	17,687
		Etched section with crust. Shows typical octahedral figures. Cat. No., 432.	160
		Section showing iron and chrysolite. Cat. No., 450.	165
		Like No. 450. Cat. No., 436.	36

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
39	Described 1890.	**Bridgewater,** Burke Co., North Carolina. Iron. Medium octahedrite, Om. Thin slab with natural and etched surfaces. Exhibits well marked Widmanstätten figures. Cat. No., 137.	19
40	Found before 1819.	**Burlington,** Otsego Co., New York. Iron. Medium octahedrite, Om. Triangular slab, etched on one surface. Shows very delicate Widmanstätten figures. Cat. No., 36.	32
41	Found before 1874.	**Butler,** Bates Co., Missouri. Iron. Finest octahedrite, Off. Etched slab. Widmanstätten figures very distinct. The plates of the latter seen with a lens appear to be made up of a number of smaller ones, which anastomose. There are also comb-like markings, made up of innumerable fine lines. Contains nodule of troilite. Cat. No., 96.	71.5
42	Fell 1861, May 12, about noon.	**Butsura,** Goruckpur, India. Stone. Intermediate chondrite, Ci. Fragments with crust and polished surfaces. Nickel-iron is present in large amount. There are also chondri 1 mm. in diameter, of a chrysolite-like mineral. The ground-mass is greenish black and structureless. Cat. No., 277.	1.85
		Cabarrus County, see Flows. **Caille,** see La Caille.	
43	Found 1891.	**Cañon Diablo,** Coconino Co., Arizona. Iron. Coarse octahedrite, Og.	
		Complete individual, apparently scaled off from a larger mass. Shows the smooth surface and characteristic pits of this iron. Cat. No., 141.	844
		Complete individual. Besides the shallow pits shown in the figure the mass is indented by deeper cylindrical ones, 3 to 4 cm. in depth. Cat. No., 143.	460,304
		Full-sized section, 20 x 29 cm., with polished and etched surfaces. The Widmanstätten figures are very coarse and arranged in approximately parallel bands. Large nodules of troilite and flakes of schreibersite are scattered through the mass. Cat. No., 144.	2,934
		Small, complete individual, like No. 141. Cat. No., 145.	165
		Complete individual. It contains a natural perforation about 3 cm. in its smallest diameter. Cat. No., 146.	120,657
		Full-sized slab, 19 x 30 cm., showing polished and etched surfaces like No. 144. Cat. No., 147.	4,309
		Nearly complete individual showing deep and shallow pits. One etched surface, 19 x 21 cm., exhibits nodules of troilite and indications of crystalline structure. Cat. No., 148.	23,590

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
		Complete individual, sub-cylindrical in form. Exhibits the characteristic pittings. Cat. No., 149.	90,898
		Thick slab, 20 x 27 cm., polished, showing nodules of troilite. Cat. No., 150.	26,047
		Hemispheroidal mass. One polished surface, 20 x 25 cm., shows troilite nodules Cat. No., 151.	24,489
		Six small fragments with natural surface. Cat. No., 152.	123
		Complete individual, showing pits and natural surface. Apparently scaled from a larger mass. Cat. No., 373.	620
		Complete individual. Cat. No., 455. Gift of George Bell.	60
		Complete individual, deeply pitted. Cat. No., 497. Gift of Ed. E. Ayer Pioneer Hose Company.	34,800
44	Found 1793.	**Cape of Good Hope,** Africa. Iron. Ataxite, with hexahedral streaks. Polished slab of brilliant nickel-white color. Cat. No., 29.	27
45	Found 1887.	**Carlton,** Hamilton Co., Texas. Iron. Fine octahedrite, Of. Full-sized, thin slab, 22 x 30 cm., showing polished and etched surfaces. The Widmanstätten figures appear as beautifully distinct and delicate lines running parallel in two directions throughout the mass. Troilite is distributed in radiating veins. Cat No., 131.	3,406
46	Found 1840.	**Carthage,** Smith Co., Tennessee. Iron. Medium octahedrite, Om. Thick slab showing natural, polished and etched surfaces Coarse Widmanstätten figures are dimly outlined on the latter. The lines of taenite are very delicate. Cat. No., 51.	50
47	Recognized 1867.	**Casas Grandes,** Chihuahua, Mexico. Iron. Medium octahedrite, Om. Etched section 12 x 13 cm., with crust. Shows typical Widmanstätten figures, the bands of kamacite being long and well-defined. Little taenite is to be seen and little troilite. Cat. No., 524.	608
48	Fell 1874, May 14, 2:30 P. M.	**Castalia,** Nash Co., North Carolina. Stone. Gray chondrite, Cg. Fragment with crust; the latter dull-black and scoriaceous. The color of the stone is dark-gray, with no metallic grains visible. Cat. No., 307.	1.5
		Fragment from interior, showing occasional metallic grains. Cat. No., 308.	6.5
49	Fell 1838, June 6, Noon.	**Chandakapoor,** Berar, India. Stone. Brecciated intermediate chondrite, Cib. Three fragments from interior, two of them polished, showing a dark-gray stone, containing numerous rusty iron grains. Cat. No., 245.	3.5

o.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
0	Fell 1812, Aug. 5, 2 A. M.	**Chantonnay,** Dep. Vendée, France. Stone. Gray chondrite, Cg. Thin chip, highly polished. Almost black, with few metallic grains. Structure not discernible megascopically. Cat. No., 232.	2
		Polished fragment with crust. Cat. No., 443.	4
1	Known 1804.	**Charcas,** San Luis Potosi, Mexico. Iron. Medium octahedrite, Om. Etched section with crust. Well marked Widmanstätten figures. Cat. No., 33.	62
2	Fell 1835, Aug. 1, 2-3 P. M.	**Charlotte,** Dickson Co., Tennessee. Iron. Fine octahedrite, Of. Thin slab, one surface etched. Typical Widmanstätten figures. Cat. No., 40.	7
3	Fell 1810, Nov. 23, 1:30 P. M.	**Charsonville,** near Orleans, Dep. Loiret, France. Stone. Veined gray chondrite, Cga. Fragment from interior. Light-gray, with rusty-brown spots, due to oxidation of the abundant metallic grains. Cat No., 229.	22
		Thin chip, polished. Like previous specimen, but traversed by a delicate black vein. Cat. No., 230.	2
4	Fell 1815, Oct. 3, 8 A. M.	**Chassigny,** Dep. Haute-Marne, France. Stone. Chassignite, Cha. Fragments from the interior. Composed of light-yellow friable chrysolite specked with black. Cat. No., 546.	0.7
5	Fell 1841, June 12, 1:30 P. M.	**Chateau Renard,** Dep. Loiret, France. Stone. Veined intermediate chondrite, Cia. Fragment from interior. Gray, compact, traversed by delicate black veins. Metallic grains small and bright. Cat. No., 249.	57
		Like previous specimen. Cat. No., 248.	7
		Like No. 249. Cat. No., 247.	5
6	Found before 1849.	**Chesterville,** Chester Co., South Carolina. Iron. Nickel-poor ataxite, Nedagolla group. Thin slab, etched. The etching brings out a network of irregular lines on the surface. Cat. No., 56.	6
7	Found 1873.	**Chulafinnee,** Cleburne Co., Alabama. Iron. Medium octahedrite, Om. Thin slab, etched. Broad Widmanstätten figures are dimly outlined. Cat. No., 94.	29
58	Found 1860.	**Cleveland,** Bradley Co., Tennessee. Lea Iron. Probably the same as Dalton. Iron. Medium octahedrite, Om. Large, thin slab, showing crust, polished and etched surfaces. Typical Widmanstätten figures. Cat. No., 127.	234

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
59	Known 1837.	**Coahuila,** Mexico.	
		Iron. Hexahedrite, H. (Sancha Estate.) Thin, polished slab, a portion etched. Cat. No., 37.	70
		Turnings. Cat. No., 90.	10
	Found 1868.	Butcher Iron. Large, thin slab, a portion etched. The latter shows a stippled surface intersected by numerous Neumann lines. Included nodules of troilite are also to be seen. Cat. No., 42.	2,140
		Large segment, showing natural, polished and etched surfaces. Natural surface very smooth. Etched surface like that of previous specimen. Cat. No., 43.	3,402
60	Fell 1838, Oct. 13, 9 A. M.	**Cold Bokkeveld,** Cape of Good Hope, Africa. Stone. Carbonaceous chondrite, K. Fragment from interior. Dull-black with white specks. Resembles a piece of graphite. Cat. No., 246.	1
61	Found 1880.	**Colfax,** Colfax Township, near Ellenboro, Rutherford Co., North Carolina.	
		Iron. Medium octahedrite, Om. Spheroidal mass, showing natural and etched surfaces and fracture. The latter shows the iron to be highly crystalline, and to possess octahedral cleavage. Cat. No., 153.	1,130
		Etched section, showing typical octahedral figures. See Plate XXXV. Cat. No., 156.	61
62	Fell 1890, Feb. 3, 1:30 P. M.	**Collescipoli,** Terni, Italy. Stone. Spherical chondrite, Cc. Fragment, with crust. Crust dull black, scoriaceous, nearly 2 mm. in thickness. Interior of stone light bluish-gray. Shows chondri and metallic grains. Cat. No., 356.	2.5
63	Known 1860.	**Coopertown,** Robertson Co., Tennessee. Iron. Medium octahedrite, Om. Thin slab, etched. The Widmanstätten figures are made up of broad plates, 5 mm. in thickness. Cat No., 83	82.5
64	Described 1840.	**Cosby's Creek,** Cocke Co., Tennessee.	
		Iron. Coarse octahedrite, Og. Several irregular fragments, all showing octahedral cleavage. Cat. No., 48.	35.5
		Irregular fragment, cleavage structure prominent. Cat. No., 49.	43
		Five fragments of about 20 grams each, cleaving in octahedrons, which are separated by bright plates of taenite. Cat. No., 53.	114
65	Found 1881.	**Costilla Peak,** Taos Co., New Mexico. Iron. Medium octahedrite, Om. Nearly full-sized etched section, 11 x 20 cm. Shows typical octahedral figures. Cat. No., 502.	1,154

Date Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
und 1887.	**Crab Orchard**, near Rockwood, Cumberland Co., Tennessee.	
	Iron-stone. Mesosiderite, M. From Mass No. 1. Thin slab showing natural and etched surfaces. The metallic grains are small and about evenly distributed, except for three large nodules, one of which, having a diameter of 1.5 cm., shows well-marked Widmanstätten figures. The metallic portion serves as a matrix to hold the siliceous grains. Cat. No., 184.	40.5
	Mass No. 2. Complete individual. The crust is reddish-brown and cracked in several places. No well-marked pits are seen. Cat. No., 185.	4,351
	Part of Mass No. 3. One-half of the original find, with natural and polished surface, 12 x 13 cm. General structure like No. 184, but the specimen shows a larger proportion of the non-metallic minerals, and these occur occasionally in large nodules. Cat. No., 186.	801
	From Mass No. 3. Large segment, 17 x 26 cm., showing natural and polished surfaces. Cat. No., 187.	6,151
	Segment from Mass No. 1, showing natural and polished surfaces. Structure like No. 184. Cat. No., 374.	806
	Irregular fragment, one surface polished. Metallic grains small and evenly distributed. Cat. No., 336.	80.4
und 1854.	**Cranbourne**, Victoria, Australia.	
	Iron. Coarse octahedrite, Og. Irregular fragment, much decomposed. A portion altered to limonite. Silvery plates of taenite are numerous through the mass. Cat. No., 68.	34.2
	Cleaved fragment, octahedral structure prominent. Cat. No., 69.	4.5
	(Yarra Yarra River.)	
	Thin slab showing natural and etched surface. Crystalline structure is indicated on the etched surface, but no distinct Widmanstätten figures are shown. Cat. No., 70.	15
	Cross Timbers, see Red River.	
	There are three "Cross Timbers" in Texas, occurring in Denton, Harris, and Johnson counties respectively. None of these is near the locality 32° 7′ N. and 95° 10′ W., at which this meteorite is reported to have been found. It is true this locality is a long distance from the Red River as well, but this name has historic usage.	
und 1877.	**Dalton**, Whitfield Co., Georgia.	
	Iron. Medium octahedrite, Om. Thin, etched section showing coarse, typical Widmanstätten figures and crust. Cat. No., 110.	81

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
69	Fell 1878. Sept. 5.	**Dandapur,** Dist. Guorckpur, India. Stone. Veined intermediate chondrite, Cia. Fragment, with crust, one surface polished. Crust black, thin, minutely pitted. Interior light-gray, much spotted with rust. The outlines of light colored chondri can be discerned here and there. Metallic grains are rather numerous. Cat. No., 449.	27.5
70	Found 1846.	**Deep Springs,** Deep Springs Farm, Rockingham Co., North Carolina. Iron. Nickel-rich ataxite. Morradal group. Nearly complete etched section 7 x 17 cm. Exhibits no figures, but shows a few troilite inclusions. Cat. No., 453.	420
71	Known 1856.	**Denton County,** Texas. Iron. Medium octahedrite, Om. Thin, sawed fragment. Along an old fracture are numerous parallel grooves which are probably lines of decomposition. Cat. No., 74.	3
72	Found before 1780.	**Descubridora,** Catorce, San Luis Potosi, Mexico. Iron. Medium octahedrite, Om. Polished and etched slab. Widmanstätten figures in long parallel bands are crossed at intervals by others nearly at right angles. Cat. No., 2.	35
73	Fell 1860, July 14, 2:15 P. M.	**Dhurmsala,** Punjaub, India. Stone. Intermediate chondrite, Ci. Fragments from interior. Cat. No., 275.	5
		Fragment with crust, the latter black, shining and showing numerous pits. Interior light-gray, with rusty grains. Compact. Nodules of a bluish gray color, finer grained than the rest, are distributed through the mass. Cat. No., 276.	123
74	Found 1888.	**Doña Inez,** Atacama, Chile. Iron-stone. Mesosiderite, M. Thin slab, showing natural and etched surfaces. The stony matter, dark-brown in color, largely predominates. One nodule of iron about the size of a pea, shows delicate Widmanstätten figures. Cat. No., 191.	48.5
		Hemispheroidal mass, one surface polished. The peculiar cracked surface characteristic of these meteorites is well exhibited. Cat. No., 192.	103
		Complete individual, described by Howell as looking like "a lump of dried red mud cracked by shrinkage and covered with spots of green mould (nickel) in places." Cat. no., 193.	741
		Similar to No. 192, but larger. Cat. No., 194.	245

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
75	Fell 1815, Feb. 18, Noon.	**Durala,** Punjaub, India. Stone. Veined intermediate chondrite, Cia. Sawed fragment with crust. Crust thick, dark and blebby. Interior gray, somewhat friable and showing coarse metallic grains. Cat. No., 559.	54
76	Found 1880.	**Eagle Station,** Carroll Co., Kentucky. Iron-stone. Pallasite, P. Sawed slab, showing natural surface deeply pitted, and polished surface. The iron matrix encloses fragments of chrysolite, some a centimeter in diameter, transparent and of brilliant luster. See Plate XXXIII. Cat. No., 180.	106
		Grains of chrysolite, separated from the iron, some coarse and some in a powdered state. Cat. No., 182.	6
77	Fell 1785, Feb. 19.	**Eichstädt,** Wittmess, Bavaria. Stone. Spherical chondrite, Cc. Fragment from interior, showing a gray, coarse ground-mass containing rusty iron grains. Cat. No., 212.	1
78	Fell 1400? Recognized 1811.	**Elbogen,** Bohemia. Iron. Medium octahedrite, Om. Etched fragment showing Widmanstätten figures. Cat. No., 1.	2.5
79	Found 1893.	**El Capitan Mts.,** Lincoln Co., New Mexico. Iron. Medium octahedrite, Om. Etched section showing crust and typical octahedral figures. Cat. No., 430.	214
		Ellenboro, see Colfax.	
80	Found 1854.	**Emmitsburg,** Frederick Co., Maryland. Iron. Medium octahedrite, Om. Etched slab with natural surface. Widmanstätten figures well brought out. Cat. No., 67.	28.5
81	Fell 1492, Nov. 16, 11:30 P. M.	**Ensisheim,** Upper Alsace, Germany. Stone. Crystalline chondrite, Ck. Fragment from interior. Dark-gray, fine grained, smooth and shining in portions. Cat. No., 207.	22
		Similar to previous specimen. Cat. No., 208.	4
82	Fell 1889, July.	**Ergheo,** Somaliland Peninsula, E. Africa. Stone. Crystalline chondrite, Ck. Polished section with crust. Polished surface brownish black, showing small metallic grains, rather thinly distributed. Texture firm, compact. Crust surface smooth and of reddish-brown color, indicating long exposure. Cat. No., 553.	192.5

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
83	Fell 1812, Apr. 15, 4 P. M.	**Erxleben,** Saxony, Prussia. Stone. Crystalline chondrite, Ck. Fragment from interior. Dark-gray, compact, made up of siliceous grains with a vitreous luster, and numerous fine, metallic grains. Cat. No., 231.	2.5
84	Fell 1879, May 10, 5 P. M.	**Estherville,** Emmet Co., Iowa. Iron-stone. Mesosiderite, M. Irregular fragment, much oxidized. Cat. No., 176.	75
		Full-sized slab, 18 x 31 cm., polished. Nickel-iron appears in large nodules, irregular flakes and a long, narrow vein, distributed through a greenish-black, structureless ground-mass. Cat. No., 177.	2,721
		Thirteen complete individuals, varying in size from a pea to a walnut. Surface like No. 175. Cat No., 178.	47
		Complete individual. Cat. No., 458. Gift of A. E. J. Svege.	1
85	Fell 1890, June 25, 1 P. M.	**Farmington,** Farmington Township, Washington Co., Kansas. Stone. Black chondrite, Cs. Fragment from interior, having the appearance of a dolerite of dark-gray color and splintery fracture. Contains white radiated chondri. Bronze-yellow metallic grains are numerous. Cat. No., 342.	120
		Thin slab, polished, showing white and dark chondri, and various grains of nickeliferous iron. Cat. No., 344.	425
		Similar to No. 343. Cat. No., 345.	672
		Full-sized slab, 15 x 40 cm., polished. Similar to above specimen. Cat. No., 346.	3,302
		Large section of complete individual, showing crust and one polished surface, 15 x 40 cm. The crust surface is smooth, but the usual pittings are absent. Bead-like projections mark the presence of metallic nodules which resisted fusion. Cat. No., 347.	13,365
		Full-sized slab, 20 x 33 cm., polished. The metallic veins first described by Preston, are beautifully exhibited in this specimen. Cat. No., 348.	2,792
		Nearly complete individual. Metallic beads are numerous on the surface, and the scale-like crust seems to be largely metallic. In other respects, like previous specimen. Cat. No., 349.	2,494
		Section showing natural and polished surfaces. Cat. No., 343.	327
86	Fell 1849, Oct. 31, 3 P. M.	**Flows,** Cabarrus Co., North Carolina. This fall is often known as Monroe, Cabarrus Co. Monroe is, however, not in Cabarrus Co., and eighteen miles distant. As the fall took place near the present post-office of Flows, this seems to be a more suitable name by which to designate the fall than Monroe.	

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
		Stone. Veined gray chondrite, Cga. Fragment from interior. Dark-gray, with white, rounded chondri and numerous metallic grains. Compact. Cat. No., 256.	
		Floyd County, see Indian Valley.	4
87	Fell 1890, May 2, 5:15 P. M.	**Forest City,** Winnebago Co., Iowa. Stone. Spherical chondrite, Cc. 677 complete individuals, ranging in weight from one-tenth of an ounce to one pound. They exhibit almost every variety of shape and degree of surface fusion. From the fully rounded specimens with thick, black crust there is every gradation to those whose rough surface is only slightly blackened, indicating that they separated from other masses only a short distance before reaching the earth. The interior, where seen, is light-gray, with coarse metallic particles. In the group is the stone which fell into a haystack without setting it on fire. Cat. Nos., 340-41, 326.	10,452.75
		Complete individual, with small, conical pittings resembling raindrop impressions. Cat. No., 340.	4,308.25
		Complete individual, with small, conical pittings resembling raindrop impressions. Cat. No., 340.	1,698
88	Found 1891.	**Forsyth County,** North Carolina. Iron. Ataxite, Nedagolla group. Polished slab. Cat. No., 568.	384
89	Fell 1829, May 8, 3:30 P. M.	**Forsyth,** Monroe Co., Georgia. Stone. Veined white chondrite, Cwa. Thin chip, polished. Ground-mass brownish-gray, containing chondri of lighter color, and scattered fine metallic grains. Also smaller fragments. Cat. No., 240.	5
		Fragment with crust. Crust black, dull, and thick Interior like previous specimen. Cat. No., 241	34
90	Found 1882.	**Fort Duncan,** Maverick Co., Texas. Iron. Hexahedrite H. Thin slab, with crust etched. The etched surface is stippled and shows Neumann lines. Small grains of troilite are visible. Cat. No., 113.	104
91	Fell 1868, Dec. 5, 3 P. M.	**Frankfort,** Franklin Co., Alabama. Stone. Howardite, Ho. Thin, sawed fragment. Light-gray with black and white grains. No metallic particles visible. Cat. No., 296.	0.5
92	Recognized 1889.	**Gilgoin,** Gilgoin Station, New South Wales. Stone. Crystalline chondrite, Ck. Polished fragment, with crust. Polished surface, black, compact, abundantly sprinkled with metallic grains. Light-colored chondri, 1 mm. in diameter are to be seen. The crust surface is rough and rusty in appearance. Cat. No., 538.	214

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
93	Fell 1853, Feb. 10, 1 P. M.	**Girgenti,** Sicily. Stone. Veined white chondrite, Cwa. Polished fragments from interior. Gray, very fine grained, with bright metallic grains. Cat. No., 263.	1.1
94	Found 1884.	**Glorieta Mountain,** Santa Fe Co., New Mexico. Iron. Medium octahedrite, Om. Slab, 11 x 13 cm., with crust, polished and etched. The well-known Widmanstätten figures of this iron are fully displayed. Cat. No., 122.	1,271
		Square section etched, showing both coarse and fine Widmanstätten figures. Cat. No., 123.	13
95	Found 1883.	**Grand Rapids,** Kent Co., Michigan. Iron. Fine octahedrite, Of. Full-sized section, 13 x 17 cm., polished and etched. Shows very distinct and striking Widmanstätten figures made up of thin plates packed together in bundles. Cat. No., 116.	1,160.5
		Full-sized, thick section, 16 x 22 cm., polished and showing Widmanstätten figures like previous specimen. Cat. No., 117.	7,881
96	Fell 1861, June 28, 7 P. M.	**Grosnaja** (Mikenskoi), Caucasus, Russia. Stone. Black chondrite, Cs. Fragments from interior. Color, black, spotted with white chondri. Occasional metallic grains. Texture compact. Cat. No., 485.	4
97	Fell 1837, July 24, 11:30 A. M.	**Gross-Divina,** Trentsiner Com., Hungary. Stone. Spherical chondrite, Cc. Fragments of interior and crust. Interior brownish-gray, friable. Crust black. Cat. No., 545.	0.56
98	Fell 1881, Nov. 19, 6:30 A. M.	**Grossliebenthal,** near Odessa, Gov. Kherson, Russia. Stone. Veined white chondrite, Cwa. Fragments, with crust. Crust black, rather smooth. Interior light-gray, fine-grained, rather friable. Shows shining metallic grains and a narrow vein. Cat. No., 549.	0.91
99	Found 1856.	**Hainholz,** Minden, Westphalia. Iron-stone. Mesosiderite, M. Thin chip, showing natural and polished surface. The metallic grains are small, and scattered through a brownish mass of asmanite and bronzite. Cat. No., 165.	10.5
		Fragment from interior. Black, fine-grained. Cat. No., 267.	1.3
100	Found 1884.	**Hammond,** St. Croix Co., Wisconsin. Iron. Compact iron with octahedral streaks, Do. Thin slab, showing one etched and one polished surface. The component granules have a peculiar, shagreened appearance, due to their grouping in smaller and larger squares and to scattered flakes of schreibersite. Cat. No., 124.	35

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
		Hartford, see Marion.	
101	Found 1895.	**Hayden Creek,** Lemhi Co., Idaho. Iron. Medium octahedrite, Om. Etched section with crust. Shows typical octahedral figures. Cat. No., 489.	51
		Henry County, see Hopper.	
102	Fell 1857, April 1, Night.	**Heredia,** Costa Rica, Central America. Stone. Brecciated spherical chondrite, Ccb. Fragment from the interior. Light-gray with metallic grains. Texture rather firm. Cat. No., 442.	4.5
103	Fell 1869, Jan. 1, 12:30 P. M.	**Hessle,** near Upsala, Sweden. Stone. Spherical chondrite, Cc. Sawed fragment, with thin, dull black crust. Metallic grains coarse and numerous. Cat. No., 297.	18
		Fragment showing crust on all but two surfaces. Cat. No., 298.	5
104	Found 1882.	**Hex River,** Cape Colony, So. Africa. Iron. Hexahedrite, H. Sawed slab, one surface etched. Neumann lines are partially discernible, but more prominent are the parallel systems of troilite plates described by Brezina. These are beautifully shown in this specimen. Cat. No, 115.	364
105	Found 1887.	**Holland's Store,** Chattooga Co., Georgia. Iron. Brecciated hexahedrite, Hb. Thin fragment with crust. Polished surface. Cat. No., 129.	28
106	Fell 1875, Feb. 12, 10:15 P. M.	**Homestead,** Iowa Co., Iowa. Stone. Brecciated gray chondrite, Cgb. Complete individual, nearly covered with crust. Surface indented with broad, shallow pits. Crust thin, dull black. Interior of stone dark-gray. Cat. No., 312.	3,175
		About three-fourths of a complete individual. Crust and interior like previous specimen. The chondritic structure is well exhibited, and metallic grains are numerous. Cat. No., 313.	7,626
		Polished slab, 16 x 20 cm. with crust. The abundance of metallic constituents is well displayed in this specimen as are also the chondri. Cat. No., 314.	1,744
107	Prehistoric. Described 1902.	**Hopewell Mounds,** Ross Co., Ohio. Iron. Medium octahedrite, Om. Fragment with etched surface. Cat. No., 480.	125.5
		Fragments, worked into beads. Cat. No., 481.	11.5

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
108	Found 1889.	**Hopper,** Henry Co., Virginia. This meteorite is usually known by the name of Henry County, but as the place of find is accurately given near the present post-office of Hopper, the above name seems desirable. Both Wülfing and Berwerth inquire whether this meteorite should not be classed with Locust Grove, but the two bear no resemblance in structure and the localities are three hundred miles apart. The Hopper iron somewhat resembles, however, that of Smith's Mountain in structure and composition and the localities are only eighteen miles apart.	
		Iron. Medium octahedrite, Om. Cleavage pieces, (octahedral) much oxidized. Cat. No., 136.	47
109	Found about 1800.	**Imilac,** Atacama, Chile. Iron-stone. Pallasite, P. Fragment of iron matrix, most of the stony filling having dropped out. Cat. No., 160.	12.5
		Like previous specimen. Cat. no., 161.	28.5
		Thick slab, polished and etched. The metallic portion exhibits occasional Widmanstätten figures. Its sponge-like pores are filled with chrysolite more or less decomposed. Cat. No., 162.	205
110	Found 1888.	**Inca** (Llano del Inca), Atacama, Chile. Iron-stone. Mesosiderite, M. Dark brown mass, with natural and polished surfaces. Metallic grains appear only on one edge. Cat. No., 188.	38
		Complete individual, intersected by the cracks so characteristic of this meteorite. A few large grains of chrysolite are enclosed in cavities on the surface. Cat. No., 189.	54.5
		Thick slab, polished on two surfaces. No metallic grains are visible. Cat. No., 190.	148
111	Fell 1891, Apr. 7.	**Indarch,** Caucasus, Russia. Stone. Carbonaceous spherical chondrite, Kc. Fragment from interior. Color, brownish black. Appears porous on account of chondri having dropped out. Numerous chondri, some of them shiny black, all spherical and up to 1.5 mm. in diameter, project from the mass. Minute, shining, metallic grains are numerous and show in one place a vein-like arrangement. Cat. No., 506.	15
112	Found 1887.	**Indian Valley,** Indian Valley Township, Floyd Co., Virginia. Iron. Hexahedrite, H. There seems to be no evidence of brecciation in this iron sufficient to warrant calling it a brecciated hexahedrite. About half of the original mass, one surface polished. This surface is of bright nickel-white color and exhibits numerous parallel rows of rhabdite inclusions. The crust surface shows rather deep pittings. Cat. No., 154.	7,426

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
		Full-sized section, 9 x 16 cm., etched. The etched surface exhibits a bright sheen flecked with granular spots arranged in lines. Two small nodules of troilite are visible. See Plate XXXVI. Cat. No., 463.	659
13	Found 1880.	**Ivanpah,** San Bernardino Co., California. Iron. Medium octahedrite, Om. Chiseled fragment which shows no evidence of cleavage. Cat. No., 112.	3
14	Found 1885.	**Jamestown,** Stutsman Co., North Dakota. Iron. Fine octahedrite, Of. Etched section, 2.5 x 11 cm., with crust. Widmanstätten figures are but dimly outlined. Cat. No., 483.	104
15	Found 1885.	**Jamyschewa** (Pawlodar), Semipalatinsk, Russia. Iron-stone. Pallasite, P. Polished fragment, made up principally of chrysolite enclosed in an iron matrix. Also some loose grains of chrysolite. Cat. No., 183.	15
16	Fell 1889, Dec. 1, 2:30 P. M.	**Jelica,** Servia. Stone. Amphoterite, Am. Fragment with crust. Crust black, rather smooth, the surface showing typical pittings. Interior gray, with angular pieces of bronzite projecting from a fine-grained ground-mass. Texture friable. Metallic grains small and scarce. An excellent specimen. Cat. No., 511.	69
17	Found 1883.	**Jenny's Creek,** Wayne Co., West Virginia. Iron. Coarse octahedrite, Og. Chiseled fragment, showing cleavage octahedrons, separated by bright plates of taenite. Cat. No., 114.	21
18	Fell 1873, June.	**Jhung,** Punjab, India. Stone. Spherical chondrite, Cc. Fragment from interior. Grayish brown, coarse-grained, chondritic, metallic particles few and small. Cat. No., 305. Thin, polished fragment, showing characters like previous specimen. Cat. No., 306.	4 2.5
19	Found 1884.	**Joe Wright Mountain,** Independence Co., Arkansas. Iron. Medium octahedrite, Om. Thin slab, etched, showing nodules of troilite and typical Widmanstätten figures. The arrangement of plates about one of the troilite nodules suggests a spherulite. Cat. No., 120.	98.5
20	Found 1866.	**Juncal,** Atacama, Chile. Iron. Medium octahedrite, Om. Thin slab with crust, etched. Shows well-marked Widmanstätten figures, the plates of taenite being very distinct. Cat. No., 140.	60

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
121	Fell 1821, June 15, 3:30 P. M.	**Juvinas,** Dep. Ardêche, France. Stone. Eukrite, Eu. Three fragments from interior. Dark-gray. Structure not well defined. No metallic grains visible. Cat. No., 237.	12
122	Known 1887.	**Kendall County,** Texas. Iron. Brecciated hexahedrite, Hb. Thin slab with natural, sawed and etched surfaces. The etched surface exhibits a coarsely granular structure, crossed by a network of delicate, straight lines. Shows numerous nodules of troilite, one 15 mm. in diameter. Cat. No., 138.	118
123	Found 1889.	**Kenton County,** Kentucky. Iron. Medium octahedrite, Om. About one-third of the original mass, showing crust and polished surface, 22 x 42 cm. Contains nodules of troilite. Cat. No., 133.	36,600
		Full-sized slab, 14 x 49 cm., etched. Widmanstätten figures very distinct and regular. Shows marked cleavage and tendency to separate along the cleavage planes. Very perfect octahedrons can be cleaved out from the mass. Cat. No., 134.	7,483
		Full-sized slab, 23 x 44 cm. Both sides polished. Cat. No., 135.	12,231
124	Fell 1869, May 22, 10 P. M.	**Kernouve** (Cléguérec), Morbihan, France. Stone. Crystalline chondrite, Ck. Fragment from interior. Cat. No., 299.	0.4
		Thin chip, one surface polished. The polished surface is grayish-brown in color, dotted with minute metallic grains, and large black chondri ½ mm. in diameter. The stone takes an excellent polish. Cat. No., 300.	2
		Thin, polished fragment. Cat. No., 301.	24
125	Fell 1850, June 13.	**Kesen,** Iwate Prefecture, Japan. Stone. Brecciated spherical chondrite, Ccb. Mass showing crust and interior. The crust surface differs little from the interior except that the metallic grains of the former have been blackened by fusion, and broad, shallow pits appear on this surface. The interior is dark-gray, compact and plentifully sprinkled with rusty iron grains. A portion of the surface is smoothed and grooved, indicating slipping along these planes. Cat. No., 257.	1,286
		Similar to previous specimen, but showing elongated pits on the crust surface. Cat. No., 258.	1,211
126	Fell 1866, June 9, 5 P. M.	**Knyahinya,** near Nagy-Berezna, Hungary. Stone. Gray chondrite, Cg. One-half of a complete individual, showing crust and polished surface, 13 x 18 cm. The latter exhibits large and small chondri, with few metallic grains. Cat. No., 284.	82

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
		Complete individual, covered with thin, black crust. Cat. No., 285.	10
		Complete individual, mostly covered with black, somewhat shining crust. Surface indented with shallow pits. Cat. No., 286.	239
		Flattened mass, showing crust and one polished surface. The crust surface is smooth and covered with small, conical pittings, giving to it the appearance of having a cellular structure. The polished surface well exhibits the aggregation of chondri which make up the mass of the stone. Some of the chondri reach a diameter 3 mm. Cat. No., 287.	3,231
		Complete individual, of irregular, pyramidal form, surface covered with shining black crust. Cat. No., 288.	82.5
127	Found 1749.	**Krasnojarsk** (Medwedewa), Gov. Jeniseisk, Siberia.	
		The Pallas Iron. Iron-stone. Pallasite, P. Fragment of the iron matrix with a little chrysolite. Cat. No., 157.	9
		Chiseled fragment showing both iron and chrysolite. Cat. No., 158.	12.5
		Several fragments, composed of iron and chrysolite. Cat. No., 159.	76.5
	Found 1891.	Sawed fragment with crust, etched. Shows typical octahedral figures. Cat. No., 505.	169
		Melnikoff regards this a separate fall.	
128	Recognized 1828.	**La Caille,** Dep. Var, France. Iron. Medium octahedrite, Om. Etched slab with crust. Displays the typical swollen octahedral figures of this meteorite. Cat. No., 541.	33
129	Found 1860.	**La Grange,** Oldham Co., Kentucky. Iron. Fine octahedrite, Of. Sawed section with crust, and etched surface. The short, narrow, irregular bands of kamacite are bordered by thin plates of taenite. Cat. No., 84.	47
130	Fell 1803, April 26, 1 P. M.	**L'Aigle,** Normandie, Dep. Orne, France.	
		Stone. Brecciated intermediate chondrite, Cib. Gray powder. Cat No., 218.	.25
		Fragment with crust. The latter thin, reddish brown, smooth. Interior grayish-brown, compact, porphyritic in appearance. Cat. No., 219.	111
		Fragment with crust and polished surface. The polished surface shows a few fine, metallic grains. Through a dark, amorphous groundmass are mingled grayish-white nodules of various sizes. Cat. No., 220.	60

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
131	Fell 1897, June 20, 8:30 P. M.	**Lançon,** Bouches-du-Rhone, France. Stone. Brecciated gray chondrite, Cgb. Fragment with crust. Interior gray, of uniform texture, with shining metallic grains. Individual chondri not clearly discernible. There are numerous slickensided surfaces running in various directions. Crust, dirty black, cracked and rough. Cat. No., 526.	85
132	Found 1857.	**Laurens County,** South Carolina. Iron. Fine octahedrite, Of. Thin slab, etched, showing beautiful Widmanstätten figures. The delicate bands, silver-white in color, and intersecting in equilateral triangles, stand out in sharp contrast to the dull-gray of the groundmass. Cat. No., 76.	13
133	Found 1814.	**Lenarto,** Saros, Hungary. Iron. Medium octahedrite, Om. Square slab, showing crust on one side and one etched surface. No Widmanstätten figures. Cat. No., 35.	47
134	Fell 1845, Jan. 25, 3 P. M.	**Le Pressoir,** Louans, Dep. Indre et Loire, France. Stone. Spherical chondrite, Cc. Fragment with crust. Crust black, smooth. Interior light-gray, somewhat rusted. Outlines of chondri are barely descernible. Cat. No., 439.	17.5
135	Fell 1896, April 13, 7:30 A. M.	**Lesves,** Namur, Belgium. Stone. Gray chondrite, Cg. Fragment with crust. Interior gray with shining metallic grains. Individual chondri are visible. Crust black and smooth. Cat. No., 542.	10.6
136	Found 1880.	**Lexington County,** South Carolina. Iron. Coarse octahedrite, Og. Thin slab with crust, etched. Etching divides the surface into irregular grains, but no regular structure is visible. Cat. No., 111.	23.5
137	Found 1834.	**Lime Creek,** Monroe Co., Alabama. Iron. Hexahedrite, H. Thin, polished slab. The etched surface bears intersecting short, straight lines of rhabdite. Cat. No., 38. Worked mass. Cat. No., 39. Section with crust. Cat. No., 434.	25.5 128 32
138	Fell 1813, Sept. 10, 6 A. M.	**Limerick,** Adare, Ireland. Stone. Veined gray chondrite, Cga. Thin chip, polished. Dark-gray, with thickly distributed rusty iron flakes. Cat. No., 233.	1.5

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
139	Known 1853.	**Lion River,** Great Namaqualand, South Africa. Probably the same as Mukerop. Iron. Fine octahedrite, Of. Etched slab, with crust. Beautiful Widmanstätten figures are displayed, the plates being narrow and very distinct. Cat. No., 62.	27
		Like No. 62, but Widmanstätten figures less distinct. Cat. No., 376.	62.5
140	Fell 1808, Sept. 3, 3:30 P. M.	**Lissa,** Bunzlau, Bohemia. Stone. Veined white chondrite, Cwa. Fragment from interior. Light-gray, with few metallic grains. White chondri of various sizes are visible here and there. Cat. No., 510.	32.5
141	Fell 1820, July 12, 5:30 P. M.	**Lixna** (Lasdany), Witebsk, Russia. Stone. Veined gray chondrite, Cga. Fragment from interior. Dark-gray with shining metallic grains. Slickensided surface. Cat. No., 550.	1.95
142	Found 1857	**Locust Grove,** Henry Co., Georgia. Iron. Ataxite, Siratik group. Thick slab with crust. Etched. Granular structure. Rhabdite inclusions. Cat. No., 558.	370.5
143	Found 1892.	**Long Island,** Phillips Co., Kansas. Stone. Crystalline chondrite, Ck. Nearly complete individual, made up of four pieces which have been placed together along the line of original fracture. Together with these is a large number of smaller pieces, varying in weight from 10,000 grammes to 5 grammes, probably also a part of the same individual at the time it fell to the earth. The surface of the main mass is indented by shallow, elliptical pits, the long axes of which run in parallel directions. The crust is smooth and brown, but in many places coated with a white incrustation of carbonate of lime, derived from the soil in which the stone lay. The interior of the mass shows a very compact, fine-grained texture, with few metallic grains; color, dark-green. The smaller fragments are much rusted by exposure. Cat. No., 350.	528,488
144	Found 1854.	**Madoc,** Hastings Co., Ontario, Canada. Iron. Fine octahedrite, Of. Spheroidal fragment showing natural surface with pittings. Cat. No., 65.	9
		Thin, sawed slab with natural surface. Cat. No., 66.	5
145	Fell 1886, Nov. 10, 3 P. M.	**Maêmê,** Hislugari, Prov. Satsuma, Japan. Stone. Veined white chondrite, Cwa. Fragment with crust. Crust black and smooth. Interior light-gray with rusty spots and metallic grains. No distinct chondri visible. Texture friable. Cat. No., 440.	7.7

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
146	Found 1840.	**Magura,** Arva, Hungary. Iron. Coarse octahedrite, Og. Irregular fragment. Cleavage structure prominent. Cat. No., 46.	137
		Fragment showing natural and etched surface. No Widmanstätten figures. Cat. No., 47.	166.5
147	Found 1852.	**Mainz,** Hesse, Germany. Stone. Crystalline chondrite, Ck. Polished fragment. Color, dark-brown, with thinly scattered metallic grains. Light-colored chondri are discernible by their outlines. Cat. No., 441.	1.8
148	Fell 1902, Jan. 6, 10 P. M.	**Majalahti,** Finland. Iron-stone. Pallasite, P. Section 10 x 5 cm., with one polished and etched surface. Shows usual sponge-like structure of pallasites, the large cavities in the nickel-iron being filled with granular chrysolite. Metallic portion nickel-white in color, not oxidized. Widmanstätten figures appear on the nickel-iron. There are two small-sized inclusions of a bronze-yellow magnetic mineral, probably schreibersite. See Plate XXXIII. Cat. No., 562.	137
149	Fell 1863, Dec. 22, 9 A. M.	**Manbhoom,** Bengal, India. Stone. Amphoterite, Am. Fragments from interior. Light-gray in color. Shows bronzite and a metallic grain. Cat. No., 551.	0.85
150	Fell 1847, Feb. 25, 2:45 P. M.	**Marion,** Linn Co., Iowa. This fall is often known as Hartford, Linn Co. Hartford is, however, a hundred miles distant and not in Linn Co. The name seems to have been applied because one of the first published letters describing the fall was dated from Hartford. As the fall took place only nine miles from Marion and this is the nearest large town as well as the county-seat, it seems to be the best name by which to designate the fall. Stone. Veined white chondrite, Cwa. Mass with crust. The crust, thick and dull black, is intersected by numerous cracks. Interior pearl-gray, abounding in minute iron grains. Delicate lines of fracture, which traverse the specimen, seem to mark slipping zones with slickensided surfaces. Cat. No., 255.	128
151	Fell 1768, Nov. 20, 4 P. M.	**Mauerkirchen,** Austria. Stone. White chondrite, Cw. Fragment with crust. Two polished surfaces show scattered metallic grains and well-marked chondri. Cat. No., 211.	110

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
152	Fell 1870.	**McKinney,** Collin Co., Texas. Stone. Black chondrite, Cs. Plano-convex mass, showing crust and polished surface. Crust reddish-brown, about 1 mm. thick. Interior greenish-black, exhibiting scattered metallic grains and outlines of chondri in almost unbroken connection. Cat. No., 355.	72
153	Described 1875.	**Mejillones,** Atacama, Chile. Iron. Brecciated hexahedrite, Hb. Thin, polished slab. The nickel-iron is distributed in a fine network and occasional nodules through an amorphous ground-mass. Cat. No., 172.	37
154	Fell 1862, Oct. 7, 12:30 P. M.	**Menow,** Mecklenburg, Germany. Stone. Crystalline spherical chondrite, Cck. Fragment from interior, made up of coarse, transparent grains with rusty metallic ones, the whole resembling a piece of brown sandstone. Cat. No., 278.	2
155	Fell 1852, Sept. 4, 4:30 P. M.	**Mezö-Madras,** Transylvania, Hungary. Stone. Brecciated gray chondrite, Cgb. Polished fragment from interior. In the dark-brown ground-mass are sharply outlined gray and white chondri, interspersed with bright, minute grains of nickel-iron. Cat. No., 260.	2
		Like previous specimen, but showing rough, dull-brown crust, not sharply separated from the interior. Cat. No., 261.	4
156	Fell 1889, June 9, 8:30 A. M.	**Mighëi,** Gov. Kherson, Russia. Stone. Carbonaceous chondrite, K. Fragment, with crust. Of dark color, somewhat resembling a piece of graphite, and so friable as to soil the fingers. Crust reddish and scoriaceous. Cat. No., 338.	1.5
		Like previous specimen, except that crust is darker. Chondri of lighter color are distributed through the mass. Cat. No., 339.	4.4
157	Fell 1842, April 26, 3 P. M.	**Milena** (Pusinsko Selo), Croatia, Hungary. Stone. White chondrite, Cw. Fragment from interior. Light-gray, with coarse and fine metallic grains. Shows distinct chondritic structure. Cat. No, 250.	6
158	Found 1857.	**Mincy,** Taney Co., Missouri. Iron-stone. Mesosiderite, M. Sawed slab, 10 x 13 cm., showing natural and polished surfaces. The metallic and non-metallic minerals are about equally abundant. Cat. No., 167.	395
		Like previous specimen except that the silicates are gathered in large nodules in certain portions. Cat. No., 168.	209
		Fragment with natural surface. Cat. No., 77.	4

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
159	Known 1804.	**Misteca,** Oaxaca, Mexico. Iron. Medium octahedrite, Om. Porous slab, etched. Widmanstätten figures quite distinct. Cat. No., 32.	86
160	Fell 1882, Feb. 3, 4 P. M.	**Mocs,** Kolos, Hungary. Stone. Veined white chondrite, Cwa. Nearly complete individual, cuboidal in form, with solid angles only slightly rounded. Interior grayish-brown in color, with coarse, metallic grains. Cat. No., 322.	179
		Elongated fragment, showing crust on two sides. Narrow, dark veins pass through the mass in several directions. Cat. No., 323.	41
		Six fragments of nearly equal size, showing crust and interior. They have in general a cuboidal form with a prominence of the solid angles. Portions of the interior display a slickensided surface. Cat. No., 324-29.	543
		Complete individual, tetrahedral in form. Entirely covered with thick, black crust, except at one point, where the light-gray interior may be seen. Cat. No., 330.	80.5
		Complete individual, plano-convex in form, the convex surface being evidently the "breast" side. The opposite face shows a thinner crust and rougher surface. Cat. No., 331.	6
		Monroe, see Flows.	
161	Fell 1810, August, Noon.	**Mooresfort,** Tipperary, Ireland. Stone. Veined gray chondrite, Cga. Fragment with crust. Crust black, somewhat shining. Interior, compact, ash-gray. Shows coarse, metallic grains and white chondri. Cat. No., 228.	7
162	Recognized 1893.	**Mooranoppin,** West Australia. Iron. Coarse octahedrite, Og. Polished and etched section with crust. Widmanstätten figures irregular, and blotched with schreiberite. Resembles Oscuro Mts. in figures. Cat. No., 540.	99
163	Fell 1826, May 19.	**Mordvinovka,** Gov. Ekaterinoslaw, Russia. Stone. White chondrite, Cw. Fragment from the interior. Light gray, flecked with rust and shining metallic grains. No distinct chondri are visible. Cat. No., 448.	15
164	Found 1887.	**Morristown,** Hamblen Co., Tennessee. Iron-stone. Mesosiderite, M. Full-sized, polished section, 8 x 14 cm. The stony and metallic portions are about equal in quantity. The nickel-iron tends to gather in large, rounded nodules. The stony portion is black and unindividualized megascopically. Cat. No., 561.	407

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
165	Found 1887.	**Mount Joy,** Mount Joy Township, Adams Co., Pennsylvania. Iron. Brecciated hexahedrite, Hb. This is classed by Berwerth as Ogg, but to the writer it has the characters of a cubic iron. Thick, etched section 10 x 13 cm., with crust. The well-known fragmental structure of this meteorite is plainly exhibited. Along the lines of union of the fragments flakes and grains of schreibersite are to be seen. Cat. No., 432.	733
166	Found 1868.	**Mount Vernon,** Christian Co., Kentucky. Iron-stone. Pallasite, P. Polished slab 15 x 15 cm. Shows network of nickel-iron holding rounded to angular masses of chrysolite. The nickel-iron is unequally distributed, occurring now in a solid mass, now in a network, and now disappearing entirely. It frequently contains inclusions of schreibersite. The chrysolite is of dark-yellow color, transparent to opaque. See Plate XXXIII. Cat. No., 567.	1,000
167	Found 1899.	**Mukerop,** near Tress, in Gibeon region, Ger. S. W. Africa. Iron. Finest octahedrite, Off. Etched slab, showing well-defined, typical Widmanstätten figures. Cat. No., 552.	40.5
		Etched slab, 11 x 7 cm., showing different figures on two sides of a median line. See Plate XXXV. Cat. No., 569.	429
168	Found 1897.	**Mungindi,** Queensland, Australia. Iron. Fine octahedrite, Of. Full-sized, etched section, 21 x 9 cm. Widmanstätten figures well marked. Numerous troilite inclusions. See Plate XXXVII. Cat. No., 461.	627
169	Found 1847.	**Murfreesboro,** Rutherford Co., Tennessee.[1] Iron. Medium octahedrite, Om. Etched slab showing distinct Widmanstätten figures, the plates of which run principally at right angles. Cat. No., 58.	20.5
170	Found 1899.	**Murphy,** Cherokee Co., North Carolina. Iron. Hexahedrite, H. Polished and etched section. Shows typical sheen of hexahedrites; also a few small troilite inclusions. Cat. No., 503.	125
171	Fell 1879, July 1, Evening.	**Nagaya,** Entre Rios, Argentina, South America. Stone. Carbonaceous chondrite, K. Small fragment, entirely black in color, one surface having a scoriaceous appearance, the remainder the luster of graphite. Cat. No., 320.	10
		Several fragments, having much the appearance of bits of black lava. Cat. No., 321.	0.5

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
172	Found 1890.	**Nagy-Vazsony,** Hungary. Iron. Medium octahedrite, Om. Thin slab showing natural, etched and polished surfaces. Typical Widmanstätten figures. Cat. No., 139.	37
173	Fell 1825, Feb. 10, Noon.	**Nanjemoy,** Charles Co., Maryland. Stone. Spherical chondrite, Cc. Fragments from interior. Light-gray, fine-grained, somewhat friable. Metallic particles thickly distributed. Cat. No., 238.	0.5
174	Found 1864.	**Nejed,** Wadee Banee Khaled, Central Arabia. Iron. Medium octahedrite, Om. Etched slab, with crust. Typical octahedral figures. See Plate XXXII. Cat. No., 523.	180
175	Found 1856.	**Nelson County,** Kentucky. Iron. Coarsest octahedrite, Ogg. Large scaling, slightly oxidized. Cat. No., 73. Large polished slab, upon which coarse Widmanstätten figures are here and there dimly outlined. Cat. No., 488.	23 455
176	Found 1872.	**Nenntmannsdorf,** near Pirna, Saxony, Germany. Iron. Hexahedrite, H. Cleavage pieces. Cat. No. 447.	3.7
177	Found 1897.	**Ness County,** Kansas. Stone. Crystalline chondrite, Ck. Nearly complete individual. Cat. No., 490.	85
178	Fell 1860, May 1, 12:45 P. M.	**New Concord,** Muskingum Co., Ohio. Stone. Veined intermediate chondrite, Cia. Nearly complete individual of flattened, tetrahedral form, angles little rounded. A smooth, somewhat shining, black crust covers the slightly pitted surface. Interior dark-gray, compact, and fine-grained. Metallic grains numerous. Cat. No., 273. Section from flattened individual, showing crust and two polished surfaces. The crust is thin, dull-black to reddish. A vein of metallic matter runs through the mass, and stands out in relief from the crust. The interior of the stone is dark-brown and gray. Metallic grains are large and abundant. Cat. No., 274.	347 753
179	Found 1895.	**Oakley,** Logan Co., Kansas. Stone. Crystalline chondrite, Ck. Polished section, 5 x 14 cm., with crust. Firm texture, black color, abundant sprinkling of metallic grains, resembling Pipecreek in this feature and approaching a mesosiderite. Rounded spots ½ mm. in diameter indicate the presence of chondri. Crust surface rusted. Cat. No., 501. Gift of Prof. H. A. Ward.	263

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
180	Fell 1887, Aug. 30, 3 P. M.	**Ochansk** (Tabory), Gov. Perm, Russia. Stone. Brecciated spherical chondrite, Ccb. Fragment with crust. The latter about 1 mm. thick, dull-black and blebby. Interior of stone light bluish-gray. Largely made up of distinct chondri. Small metallic grains are numerous. Cat. No., 335.	23.5
181	Known 1856.	**Orange River**, Garib, South Africa. Iron. Medium octahedrite, Om. Sawed section with natural surface, smooth and deeply pitted. Cat. No., 71.	114
		Etched slab, showing typical Widmanstätten figures and nodule of troilite. Cat. No., 72.	95.5
182	Fell 1864, May 14, 8 P. M.	**Orgueil**, Dep. Tarn et Garonne, France. Stone. Carbonaceous chondrite, K. Coarse, black powder, soft and friable. Cat. No., 282.	1
		Fragments similar to No. 282, some of them showing crust. Cat. No., 509.	20
183	Fell 1868, July 11.	**Ornans**, Doubs, France. Stone. Spherical chondrite, ornansite, Cco. Fragment, sawed from interior. Resembles a lump of hardened, sandy mud. Cat. No., 294.	19.5
184	Found 1895.	**Oscuro Mountains**, Socorro Co., New Mexico. Iron. Medium octahedrite, Om. Etched section with crust. Resembles Mooranoppin. Widmanstätten figures irregular. Surface spotted with inclusions. Crust surface jagged and torn. See Plate XXXII. Cat. No., 457.	113
185	Fell 1855, May 11, 3:30 P. M.	**Ösel** (Kaande), Island of Ösel, Livonia, Russia. Stone. White chondrite, Cw. Fragments with crust. Interior light-gray with rusty and bright metallic grains. Friable. Crust .5 mm. thick, dull-black, papillated. Cat. No., 264.	2
186	Fell 1857, Feb. 28, Noon.	**Parnallee**, Madras, India. Stone. Veined gray chondrite, Cga. Fragment with crust. The latter is thin, brownish-black and differs little from the rest of the stone. The interior is coarse-grained, with few metallic grains. Cat. No., 270.	3.5
		Fragment with crust, one surface polished. The polished surface is mottled with gray and white chondri of various sizes. Large grains of troilite are visible and minute nickel-iron grains. This meteorite should be classed as an intermediate chondrite. Cat. No., 437.	167
187	Fell 1863, Aug. 8, 12:30 P. M.	**Pillistfer**, Livonia, Russia. Stone. Crystalline chondrite, Ck. Fragment from interior. Dark-gray, compact. Made up of dark, transparent grains with a large number of minute specks of troilite. Cat. No., 279.	1

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
188	Found 1887.	**Pipecreek,** Brandera Co., Texas. Stone. Crystalline chondrite, Ck. Irregular fragment, with one polished surface. A dark, heavy stone, with a large proportion of metallic grains. Cat. No., 337.	84
189	Found 1850.	**Pittsburg** (Miller's Run), Allegheny Co., Pennsylvania. Iron. Hexahedrite, H. Etched fragment with crust. No Widmanstätten figures are visible. Cat. No., 433.	4.7
190	Fell 1723, June 22.	**Ploschkowitz,** Bunzlauer District, Bohemia. Stone. Brecciated spherical chondrite, Ccb. Oxidized fragments bearing thin, black crust. Cat. No., 493.	2.2
191	Fell 1819, Oct. 13, 8 A. M.	**Politz,** near Gera, Reuss, Germany. Stone. Veined white chondrite, Cwa. Fragment from interior. Dark-gray, with metallic grains. Cat. No., 236.	0.5
192	Recognized 1893.	**Prairie Dog Creek,** Decatur Co., Kansas. Stone. Spherical crystalline chondrite, Cck. Fragment from interior. Texture compact. Color rusty-brown with shining, minute metallic grains. A distinct chondrus, 1 mm. in diameter, is almost separated from the mass. Cat. No., 563.	25
193	Fell 1868, Jan. 30, 7 P. M.	**Pultusk,** Sielce, Nowy, Gostkówo, etc., Poland. Stone. Veined gray chondrite, Cga. Part of a large individual, showing crust and interior. The former, dull-black, papillated; the latter, gray with rusty iron grains. All fine-grained. Cat. No., 289.	350
		49 complete individuals, varying in size from a pea to a walnut. All covered more or less with crust, in some cases showing complete fusion of the surface, in others only a smoking of the same. Cat. No., 290.	740
		Seven complete individuals of larger size than previous specimens. Covered with crust. Cat. No., 291-2.	506
194	Found 1885.	**Puquios,** Chile. Iron. Medium octahedrite, Om. Full-sized slab, etched. Irregular Widmanstätten figures are dimly brought out by the etching, also flakes of schreibersite. Cat. No., 377.	154
195	Found 1839.	**Putnam County,** Georgia. Iron. Fine octahedrite, Of. Cleavage pieces showing octahedral form, separated by thin plates of taenite. Cat. No., 44.	4.5

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
196	Found 1882.	**Rancho de la Pila,** Durango, Mexico. Iron. Medium octahedrite, Om. Etched slab, 6.5 x 11 cm. with crust. Exhibits a coarsely granular structure, but no octahedral figures. There are numerous partings, some of which are quite open. Cat. No., 521.	180
197	Found 1810.	**Rasgata,** Zipaquira, U. S. of Colombia. Iron. Nickel-poor ataxite, Nedagolla group, Dn. Thin, polished fragment. Cat. No., 435.	2
198	Found 1808.	**Red River,** Texas. (Gibbs meteorite.) Iron. Medium octahedrite, Om. Chiseled fragment, one end etched. Symmetrical Widmanstätten figures are shown. Cat. No., 34.	55
199	Found 1895.	**Reed City,** Osceola Co., Michigan. Iron. Coarse octahedrite, Og. Etched section with crust. Shows coarse Widmanstätten figures and elongated and branching inclusions of schreibersite. Cat. No., 560.	137
200	Fell 1828, June 4, 8:30 A. M.	**Richmond,** Henrico Co., Virginia. Stone. Crystalline spherical chondrite, Cck. Fragment from interior. Composed chiefly of dark, angular, vitreous and coarse metallic grains. Cat. No., 239.	2
201	Found 1892.	**Roebourne,** Queensland, Australia. Iron. Medium octahedrite, Om. Full-sized, etched section, 22 x 10 cm. Typical octahedral figures are dimly outlined. Cat. No., 460.	1,480
202	Found 1896.	**Sacramento Mountains,** Eddy Co., New Mexico. Iron. Medium octahedrite, Om. Full-sized, etched section, 12 x 40 cm. Shows typical, well-defined Widmanstätten figures, and two large nodules of troilite, one of the latter perforated. See Plate XXXVI. Cat. No., 465.	2,330
203	Found 1888.	**Saint Genevieve County,** Missouri. Iron. Fine octahedrite, Of. Thick slab 12.5 x 9.5 cm., etched. Typical octahedral figures of great clearness and regularity are exhibited. There are two small inclusions of troilite. See Plate XXXVI. Cat. No., 512. Gift of Prof. H. A. Ward.	790
204	Fell 1898, Nov. 15, 9:30 P. M.	**Saline,** Saline Township, Sheridan Co., Kansas. Stone. Crystalline spherical chondrite, Cck. Larger part of complete individual. Crust black, with metallic points and one large globule of metal. Interior compact, greenish-black in color, and shows abundant metallic grains. See Plate XXX. Cat. No., 527.	19,500

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
		Nearly full-sized section, 13 x 17 cm., one surface polished. Metallic grains show tendency to arrangement in veins. Outlines of abundant small chondri are discernible. See Plate XXXI. Cat. No., 565.	675
205	Found 1897.	**San Angelo,** Tom Green Co., Texas. Iron. Medium octahedrite, Om. Full-sized, etched section, 12 x 27 cm. Shows typical octahedral figures, with circular and elongated inclusions of troilite, the latter often distributed in a vein-like manner. Cat. No., 478.	1,501
206	Recognized 1887.	**San Emigdio Range,** San Bernardino Co., California. Stone. Spherical chondrite, Cc. Thirteen fragments from interior, one bearing crust. Rusty-brown, with metallic grains. Crust black. Cat. Nos., 446, 451.	12.5
207	Known 1883.	**São Julião de Moreira,** Minho, Portugal. Iron. Brecciated hexahedrite, Hb. Etched fragment, with crust. Cat. No., 536.	30
		Full-sized, polished section, 13 x 27 cm., with crust. Shows coarse, irregular inclusions of schreibersite. See Plate XXXIV. Cat. No., 556.	1,782
208	Fell 1868, Sept. 8, 2:30 A. M.	**Sauguis,** Dep. Basses-Pyrénées, France. Stone. Veined white chondrite, Cwa. Fragment with crust and polished surface. Crust black and shining, about 1 mm. in thickness. Interior brownish-gray, with scattered metallic particles. Cat. No., 295.	4
209	Fell 1846, Dec. 25, 2:45 P. M.	**Schönenberg,** Swabia, Bavaria. Stone. Veined white chondrite, Cwa. Fragment with crust. The latter is thick, somewhat shining and scoriaceous. The interior is dark-gray, shows metallic grains and light and dark chondri and is traversed by narrow, branching veins of nickel-iron. Cat. No., 254.	8.2
210	Found 1867,	**Scottsville,** Allen Co., Kentucky. Iron. Hexahedrite, H. Full-sized slab, 12 x 17 cm., etched. Contains a circular nodule of troilite. The etched surface has the appearance of a network of delicate, straight lines overlaying a granular base. Cat. No., 91.	364
211	Fell 1871, May 21, 8:15 A. M.	**Searsmont,** Waldo Co., Maine. Stone. Spherical chondrite, Cc. Fragment from interior. Light-gray. Cat. No., 302.	0.25
		Various fragments from interior. Light-gray, with metallic grains of silvery lustre. Chondritic structure. Cat. No., 303.	3

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
212	Found 1847.	**Seeläsgen**, Brandenburg, Prussia. Iron. Coarsest octahedrite, Ogg. Chiseled fragment. No cleavage structure visible. Cat. No., 57.	41.5
		Etched slab, containing large nodule of troilite. The iron is seen to be made up of large irregular plates. Cat. No., 375.	12.5
213	Fell 1773, Nov. 17, Midnight.	**Sena** (Sigena), Aragon, Spain. Stone. Brecciated gray chondrite, Cgb. Fragment from the interior. Compact, mottled white, gray, and brown from presence of chondri and rusty metallic grains. Cat. No., 445.	5.2
214	Found 1850.	**Seneca Falls**, Seneca Co., New York. Iron. Medium octahedrite, Om. Sawed section showing natural surface and fracture. Octahedral cleavage very distinct. One surface partially etched, bears an initial of the name of the first owner, Mr. L. C. Partridge. Cat. No., 60. Loaned by Gen. G. Murray Guion.	300
215	Fell 1865, Aug. 25, 11 A. M.	**Senhadja**, Aumale, Algiers, Africa. Stone. Veined white chondrite, Cwa. Slice from interior. Ash-gray, few metallic grains. Chondritic structure. Cat. No., 283.	1.5
216	Fell 1794, June 16, 7 P. M.	**Siena**, Tuscany, Italy. Stone. Howarditic chondrite, Cho. Fragments from interior. Dark-gray, with no metallic grains visible. Cat. No., 547.	0.25
217	Found 1887.	**Silver Crown**, Laramie Co., Wyoming. Iron. Coarse octahedrite, Og. Etched slab with crust. Structure coarsely crystalline, with a few rectilinear figures. Lines of taenite very distinct. Cat. No., 130.	71
218	Found 1863.	**Smith's Mountain**, Rockingham Co., North Carolina. Iron. Fine octahedrite, Of. Section with crust, etched. Well marked Widmanstätten figures. Some of the bands are of oval shape. Cat. No., 85.	17
		Large etched section. Cat. No., 452.	231
219	Found 1840.	**Smithville** (Caryfort), Dekalb Co., Tennessee. Iron. Coarse octahedrite, Og. Thin slab, one surface etched, but showing no Widmanstätten figures. Troilite nodules and flakes of schreibersite appear on the etched portion. Cat. No., 50.	55
220	Fell 1877, Oct. 13, 2 P. M.	**Sokobanja**, near Alexinac, Servia. Stone. Spherical chondrite, Cc. Irregular fragment of light-gray color, showing chondri, some of which are 2 mm. in diameter, also grains of troilite and nickel-iron. Friable. Cat. No., 319.	33

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
221	Fell 1876, June 28, 11:30 A. M.	**Ställdalen,** Sweden. Stone. Brecciated gray chondrite, Cgb. Fragment with crust. The latter black and shining. Interior of the stone dark-gray. Cat. No., 315.	3
		Irregular mass, with crust and polished surface. Interior brownish-black. Compact, with numerous metallic grains. There seems to be reason to doubt whether this specimen is really Ställdalen. Cat. No., 316.	50
222	Fell 1808, May 22, 6 A. M.	**Stannern,** Moravia, Austria. Stone. Eukrite, Eu. Fragment from interior. Light-gray. Structure coarse-granular, not chondritic. Cat. No., 225.	7.5
		Fragment with crust; the latter glossy-black, veined. Interior greenish-black, brecciated. Shows one large grain of troilite. Cat. No., 226.	23.5
		Fragment from interior, similar to No. 225. Cat. No., 227.	1.5
223	Found 1858.	**Staunton,** Augusta Co., Virginia. Iron. Medium octahedrite, Om. Full-sized slab, 12 x 23 cm., polished and etched. Shows typical Widmanstätten figures and large nodule of troilite. The latter nearly encloses a portion of nickel iron. Cat. No., 78.	1,595
		Slab with crust, etched. The crystalline plates have an ovoid form, and intersect very irregularly. Cat. No., 79.	665
		Slab with crust, polished and etched on two surfaces. Beautiful, broad and distinct Widmanstätten figures. Cat. No., 80.	100.5
224	Found 1724.	**Steinbach** (including Rittersgrün), Saxony, Germany. Iron-stone. Siderophyr, S. Thin slab, polished. The stony portion exceeds the metallic. Cat. No., 164.	33.5
	Found 1861.	Breitenbach. Thin, polished slab. Resembles the Steinbach specimen very closely. Cat. No., 169.	1
225	Fell 1753, June 3, 8 P. M.	**Tabor** (Krawin), Bohemia. Stone. Brecciated spherical chondrite, Ccb. Fragment from interior. Light-gray with rusty iron spots. Cat. No., 209.	.06
226	Found 1853.	**Tazewell,** Claiborne Co., Tennessee. Iron. Finest octahedrite, Off. Slab, showing natural and etched surface. Cat. No., 64.	17
227	Found 1886.	**Thunda,** Windorah, Queensland, Australia. Iron. Medium octahedrite, Om. Sawed slab, one surface etched. Widmanstätten figures distinct and regular. Cat. No., 128.	154

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
228	Found 1784.	**Toluca,** Mexico. Iron. Medium octahedrite, Om.	
		Complete individual. Form spheroidal. Cat. No., 7.	464.5
		Complete individual. Irregular form. Octahedral cleavage well exhibited. Cat. No., 8.	99.5
		Complete individual. Spheroidal form. Cat. No., 9.	263.5
		Complete individual. Shows use as a hammer. Cat. No., 10.	251
		Complete individual. Spheroidal form. Cat. No., 11.	227
		Spheroidal individual, with one etched face showing typical, coarse Widmanstätten figures and nodules of troilite. Cat. No., 12.	816
		Complete individual, showing distinct octahedral cleavage. Cat. No., 13.	112.5
		Complete individual. Cat. No., 14.	225.5
		Crescent-shaped mass, with surface 20 x 40 cm., etched. Shows coarse Widmanstätten figures and nodules of troilite of various shapes and sizes. Cat. No., 15.	16,665
		Similar to above specimen, but smaller. Surface 13 x 20 cm. Cat. No., 16.	6,166
		Broken fragment, showing well developed cleavage planes. Cat. No., 17.	1,997
		Complete individual. Surface pitted and covered with crust. Cat. No., 18.	3,000
		Scalings from previous specimen. Cat. no., 19.	60
		Complete individual. Cat. No., 20.	1,880
		Complete individual, spheroidal. Surface very smooth. Cat. No., 21.	1,107
		Complete individual, hemispheroidal. Cleavage planes well marked. Cat. No., 22.	28,038
		Complete individual, hemispheroidal. Shallow pits appear on the surface. Cat. No., 23.	46,040
		Complete individual, spheroidal. Surface smooth and pitted. Cat. No., 24.	18,025
		Etched section, 18 x 22 cm. The Widmanstätten figures are very distinct and regular. Nodules of troilite of various shapes are included. Cat. No., 25.	1,900
		Like previous specimen, but Widmanstätten figures less distinct. Surface 21 x 38 cm. Cat. No., 26.	2,423
		Complete individual, crescentic in form. Shows strong tendency to scaling and decomposition. Drops of lawrencite appear on the surface. Cat. No., 27.	19,954
		Section of flattened individual, with etched surface, 17 x 17 cm. The latter shows coarse, well-marked Widmanstätten figures and several irregular nodules of troilite. Natural surface deeply pitted. Cat. No., 370.	4,535
		Full-sized slab, 10 x 21 cm., etched. Shows the usual Widmanstätten figures and coarse, vein-like masses of troilite. Cat. No., 371.	823
		Complete individual, showing pittings and natural surface. Form, pyramidal. Cat. No., 372.	2,506

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
	Found 1897.	Los Reyes. Complete individual. Small surface etched. Cat. No., 454.	19,500
229	Found 1859-1886.	**Tombigbee River,** Choctaw and Sumter Counties, Alabama. Iron. Ataxite, D. While Berwerth classifies this iron as an ataxite the structure is in many ways cubic. The analysis does not quite accord with those of cubic irons however, and a new analysis is desirable. Etched section 10 x 14 cm., with crust. Shows numerous Neumann lines intersecting at right angles. There are numerous irregular inclusions of schreibersite of nickel-white color. Cat. No., 504.	1,690
230	Found 1863-4	**Tomhannock Creek,** Rensselaer Co., New York. Stone. Brecciated gray chondrite, Cgb. Fragment from interior, polished. Made up chiefly of metallic grains, and a dark-brown, chrysolite-like mineral. Cat. No., 280.	1
		Slice, showing crust. Interior portion like previous specimen. Cat. No., 281.	7.5
231	Found 1886.	**Tonganoxie,** Leavenworth Co., Kansas. Iron. Medium octahedrite, Om. Full-sized, etched section 8 x 12 cm., with crust. Shows typical octahedral figures with small troilite inclusions bordered by kamacite. Cat. No., 477.	264
232	Fell 1863, Dec. 7, 11 A. M.	**Tourinnes-la-Grosse,** Belgium. Stone. White chondrite, Cw. Fragment from interior. Light-gray, with minute metallic grains. Outlines of chondri not discernible. Friable. Cat. No., 486.	3
233	Found 1858.	**Trenton,** Washington Co., Wisconsin. Iron. Medium octahedrite, Om. Thin slab, etched, showing typical Widmanstätten figures, the plates of which intersect at angles of 35°. Cat. No., 81.	137
234	Fell 1856, Nov. 12, 4 P. M.	**Trenzano,** near Brescia, Italy. Stone. Veined spherical chondrite, Cca. Cubical fragment, with crust on two surfaces. The latter shining, black, only slightly pitted, 3 mm. thick. Interior very compact, coarse-grained, the metallic portion forming a network which encloses dark, spherical chondri, some of a diameter of 2 mm. Cat. No., 268.	57
		Smaller fragment, like previous specimen. Cat. No., 325.	2
235	Recognized 1851.	**Tucson,** Pima Co., Arizona. Iron. Nickel-rich ataxite, Muchachos group. Etched fragment showing typical stippled appearance of this iron. Cat. No., 59.	12

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
236	Fell 1884, May 20, 8:30 P. M.	**Tysnes,** Tysnes Island, Norway. Stone. Brecciated intermediate chondrite, Cib. Fragment from interior. Texture compact and firm. Color grayish-brown, mottled with white and gray. There are also angular inclusions of a lighter color. This stone would seem to be an intermediate chondrite, rather than a gray chondrite, as it is usually designated. Cat. No., 543.	28
237	Found 1853.	**Union County,** Georgia. Iron. Coarsest octahedrite, Ogg. Cleavage fragments with surface considerably oxidized. Cat. No., 63.	1.5
238	Recognized 1861.	**Vaca Muerta** (Sierra de Chaco), Chile. Iron-stone. Mesosiderite, M. Fragment with crust. Structure fine-granular, with metallic and non metallic minerals about equally distributed Cat. No., 170.	17.5
		Similar to No. 170, except that the surface appears glazed and shines in iridescent colors. Cat. No., 171.	14.5
239	Fell 1880, May 1-15.	**Veramin,** Teheran, Persia. Iron-stone. Mesosiderite, M. Fragment from interior. Cat. No., 495.	8
240	Fell 1831, May 13.	**Vouillé,** near Poitiers, Dep. Vienne, France. Stone. Veined intermediate chondrite, Cia. Fragment with crust. Interior gray, compact, flecked with rusty iron grains. Several delicate black veins traverse the specimen. Cat. No., 242.	53
		Thin chip, polished. Well-marked chondri make up the larger part of the mass. Fine metallic grains are numerous. Cat. No., 243.	3
241	Found 1874.	**Waconda,** Mitchell Co., Kansas. Stone. Brecciated spherical chondrite, Ccb. Mass from interior. For the most part light-gray in color, the remaining portion harder and darker. Large chondri are visible in the latter portion. Cat. No., 309.	2,835
		Fragment with crust. The latter thin, dull-black, blebby. A dark vein passes through a portion of the specimen. Cat. No., 310.	125
		Fragment from interior. Much weathered. Cat. No., 311.	5.5
242	Fell 1877, Jan. 3, 7:15 A. M.	**Warrenton,** Warren Co., Missouri. Stone. Spherical chondrite, ornansite, Cco. Fragment from interior. Resembles a piece of hardened, sandy mud or blue clay, with a few metallic grains visible. Cat. No., 317.	5

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in gram
243	Found 1888.	**Welland,** Ontario, Canada. Iron. Medium octahedrite, Om. Segment, 11.5 x 7.5 cm., showing etched and natural surfaces. Widmanstätten figures distinct and regular. Scattered grains of troilite are present. A marked tendency to octahedral cleavage is apparent. Cat. No., 132.	715.5
244	Fell 1807, Dec. 14, 6:30 A. M.	**Weston,** Fairfield Co., Connecticut. Stone. Brecciated spherical chondrite, Ccb. Fragment with crust. The latter thin, dull-black. Interior divided into yellowish and bluish-gray portions distinctly separated in outline and color. The chondri, of which the mass is largely made up, give it the appearance of a fine conglomerate. Cat. No., 224. Small fragment. Cat. No., 223.	9 3.5
245	Known 1836.	**Wichita County,** Texas. Iron. Coarse octahedrite, Og. Etched section, 18 x 27 cm. Shows coarse Widmanstätten figures, nodules of troilite and scattered flakes of schreibersite. Cat. No., 41.	1,396
246	Fell 1795, Dec. 13, 3:30 P. M.	**Wold Cottage,** Yorkshire, England. Stone. Veined white chondrite, Cwa. Three polished chips, showing chondri and metallic grains, both coarse and fine. Cat. No., 215.	2
247	Recognized 1858.	**Wooster,** Wayne Co., Ohio. Iron. Medium octahedrite, Om. Etched fragment, showing typical octahedral figures. Cat. No., 494.	2.7
248	Fell 1852, Jan. 23, 4:30 P. M.	**Yatoor,** near Nellore, Madras, India. Stone. Spherical chondrite, Cc. Fragments from interior. Gray, with dark chondri and rusty iron grains. Cat. No., 259.	1
249	Found 1884.	**Youndegin,** Western Australia. Iron. Coarse octahedrite, Og. Full-sized, elongated slab, 10 x 27 cm., showing pittings, crust, polished and etched surface. The Widmanstätten figures are coarse, many of the plates being 1.5-2 cm. in thickness. They are also crossed by a series of finer plates nearly at right angles. Troilite and schreibersite are present. See Plate XXXVII. Cat. No., 118.	1,087
250	Recognized 1792.	**Zacatecas,** Mexico. Iron. Brecciated octahedrite, Obz. Thin fragment, etched. No Widmanstätten figures. Cat. No., 28.	5.7
251	Fell 1897, Aug. 1, 10:30 A. M.	**Zavid,** Bosnia. Stone. Brecciated gray chondrite, Cgb. Fragment from interior of uniform gray color, with minute, shining metallic grains. Texture rather firm. One surface is slickensided and evidences of brecciation are seen in other portions. Cat. No., 548.	23.5
		Total number falls and finds - 251 Total weight of collection - 2,289,786 grams	

TERRESTRIAL NICKEL-IRONS.

The following Terrestrial Nickel-Irons are catalogued with the collection because of their relation in composition to iron meteorites.

No.	Date of Fall or Find.	NAME AND DESCRIPTION.	Weight in grams.
	Described 1885.	**Gorge River,** Awarua Bay, New Zealand. Sand, containing awaruite. Cat. No., 361.	50
	Described 1892.	**Josephine and Jackson Counties,** Oregon. Josephinite pebble. Cat. No., 367.	1
	Found 1870.	**Ovifak,** Disko Island, Greenland.	
		Crescentic mass, one surface showing polished, homogeneous metal. Cat No., 357.	11,000
		Hemispherical mass, one surface polished. Cat. No., 358.	1,038
		Like no 358. Cat. No., 359.	861
	Known 1873.	**Santa Catharina,** Rio San Francisco do Sul, Brazil. The origin of this iron is still in doubt, but to the writer it seems more anomalous as a meteoric than as a terrestrial iron. It seems desirable to class as meteorites only those known to be such, and hence, until confirmation of the meteoric character of this iron can be obtained, it may well be classed as terrestrial.	
		Spheroidal mass, having the well-known limonite-yellow color of the Santa Catharina iron. More or less honey-combed by decay. Cat. No., 97.	217
		Similar to previous specimen except that one surface is polished, showing a compact metalloid interior. Cat. No., 99.	921
		Similar to No. 97. Cat. No., 100.	2,579
		Similar to No. 97. Cat. No., 103.	4,252
		Mass only slightly altered, of iron-black color and metallic lustre. Cat. No., 98.	261
		A number of fragments of various sizes, apparently altered to limonite. Cat. No., 101.	1,814
		Similar to No. 97. Cat. No., 102.	766
		Similar to No. 97. Cat. No., 104.	3,344
		Similar to No. 97. Cat. No., 105.	10,884
		Similar to No. 97. Cat. No., 106.	11,576
		Similar to No. 97. Cat. No., 107.	3,174
		Similar to No. 97. Cat. No., 108.	1,577

CASTS OF METEORITES.

About 70 casts or models of meteorites, illustrating the size, form nd superficial appearance of original masses, belong to the collection. The following is a list:

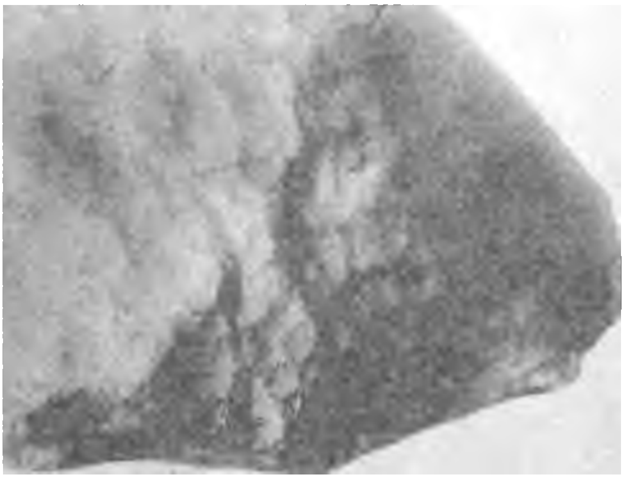
Akburpoor, India	Cat. No.,	386
Algoma, Wisconsin	"	530
Babb's Mill, Tennessee	"	383
Bath Furnace, Kentucky	"	566
Barranca Blanca, Chile	"	466
Bella Roca, Mexico	"	380
Bluff, Fayette Co., Texas	"	421
Braunau, Bohemia	"	388
Brenham, Kiowa Co., Kansas	"	418
Bustee, India	"	387
Butsura, India	"	398
Butsura, India, 5 kg.	"	398a
Butsura, India, 151 gr.	"	398b
Butsura, India, 9 kg.	"	398c
Butsura, India, 4 kg.	"	398d
Cabin Creek, Arkansas	"	411
Carlton, Texas	"	415
Charlotte, Tennessee	"	470
Chupaderos, Chihuahua, Mexico, 14,114 kg.	"	422
Chupaderos, Chihuahua, Mexico, 6,767 kg.	"	423
Cleveland, East Tennessee	"	410
Concepcion, Chihuahua, Mexico, 3,325 kg.	"	425
Crab Orchard, Tennessee—		
Mass No. 1	"	412
Mass No. 2	"	413
Mass No. 3	"	414
Cronstadt, Orange Free State, South Africa	"	471
DeCewsville, Canada	"	479
Descubridora, Catorze, Mexico, (2) 575 kg.	"	426
Durala, India	"	382
Farmington, Washington Co., Kansas	"	419

a Mountain, New Mexico	Cat. No.,	408
ra, India (2)	"	402
Divina, Hungary	"	385
iver, South Africa	"	406
tead, Iowa	"	404
Mountains, Servia	"	476
India	"	472
ight Mountain, Arkansas	"	407
Chile	"	400
County, Kentucky	"	417
ur, India	"	395
d, Griqualand, South Africa	"	429
berg, Bavaria	"	403
litas, Chile	"	399
, Oaxaca, Mexico, 421 kg.	"	428
lla, India	"	473
Arabia	"	468
ncord, Ohio	"	396
irchen, Germany	"	474
ee, India	"	393
s, Chile	"	409
de la Pila (Cacaria), Durango, Mexico	"	420
, England	"	475
Township, Sheridan Co., Kansas	"	525
egorio, Chihuahua, Mexico, 11,000 kg.	"	424
, Russia	"	391
ille, Allen Co., Kentucky	"	401
ie, India (5)	"	390
n, Virginia	"	394
ch, Bohemia	"	397
e, India	"	467
a, Chile	"	377
d, Canada	"	416
e Udinsk, Siberia	"	392
a County, Texas	"	384
ottage, England	"	381
, India	"	389
as, Mexico, 780 kg.	"	427

MICRO-SECTIONS.

Thin sections available for microscopic study are possessed of the following falls:

Aussun, Bremervorde, Crab Orchard, Farmington, Forest City, Homestead (3), Kernouve, Kesen, Knyahinya, L'Aigle, Long Island (5), Mocs, Ness County, New Concord, Oakley, Parnallee, Pultusk, Sauguis, Simbirsk and Stannern.



[illegible]

Baratta X [illegible]

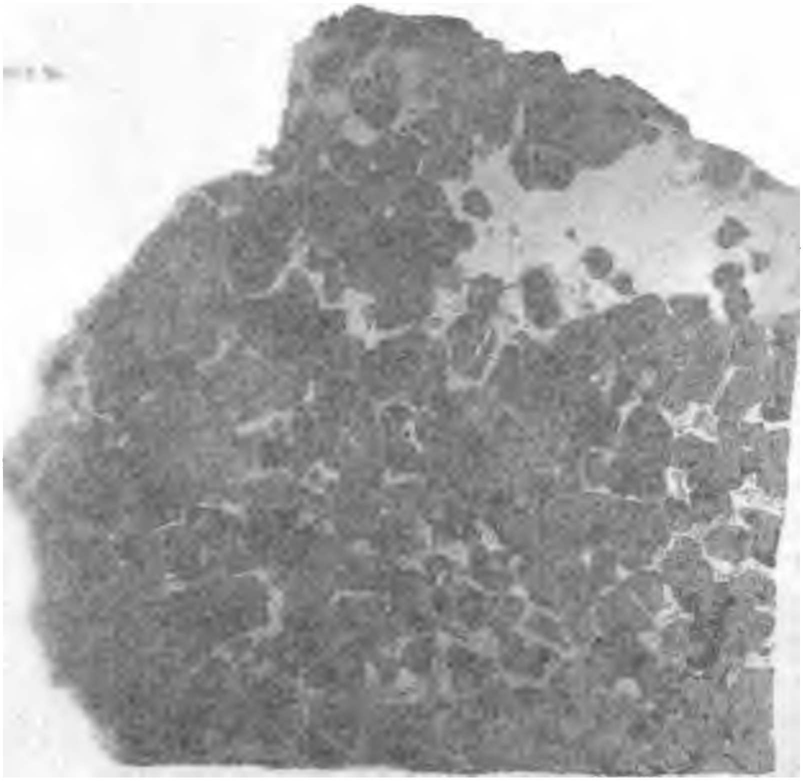
[illegible]

[illegible]

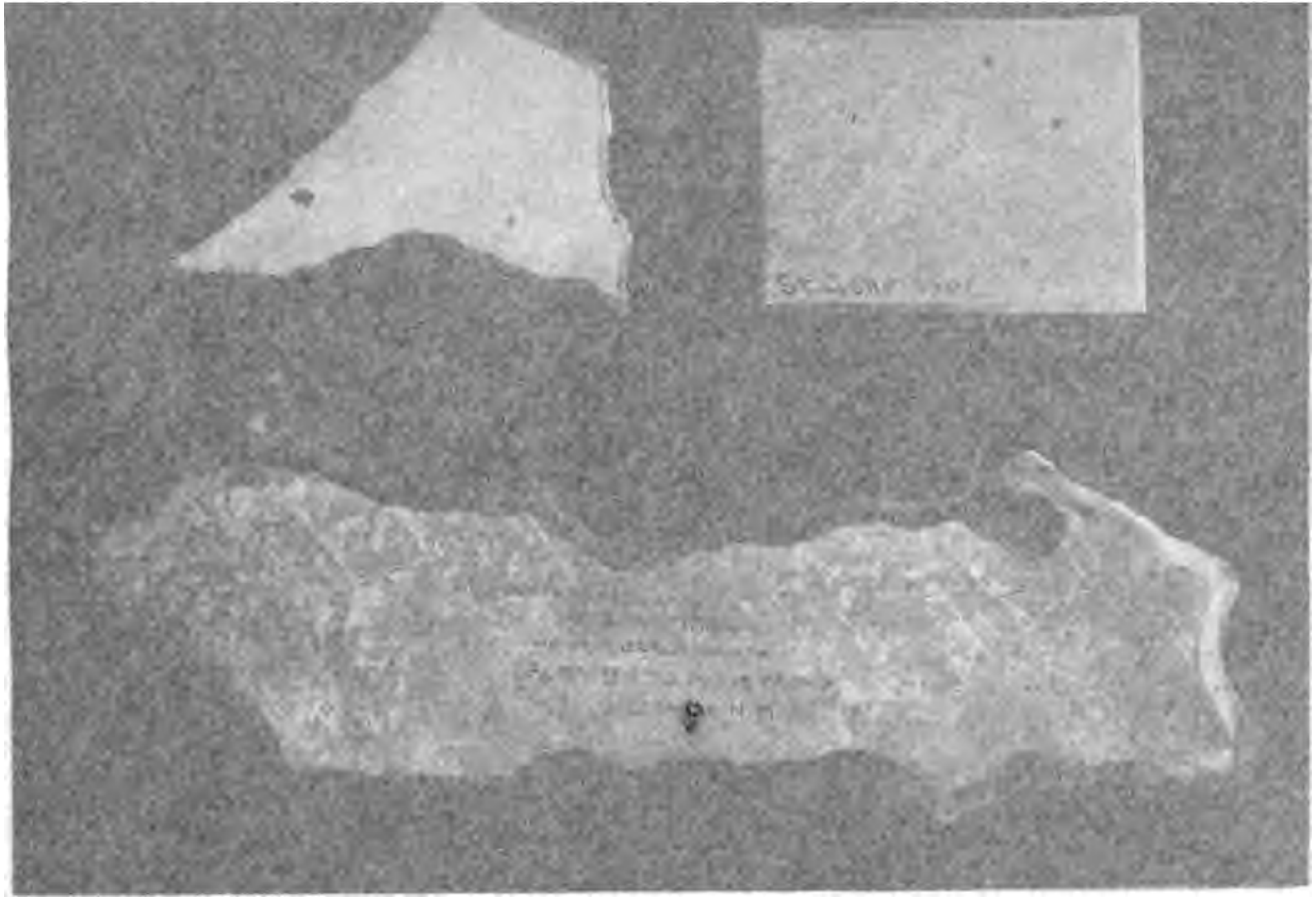
[illegible]

[illegible]

Marjalahti x ½



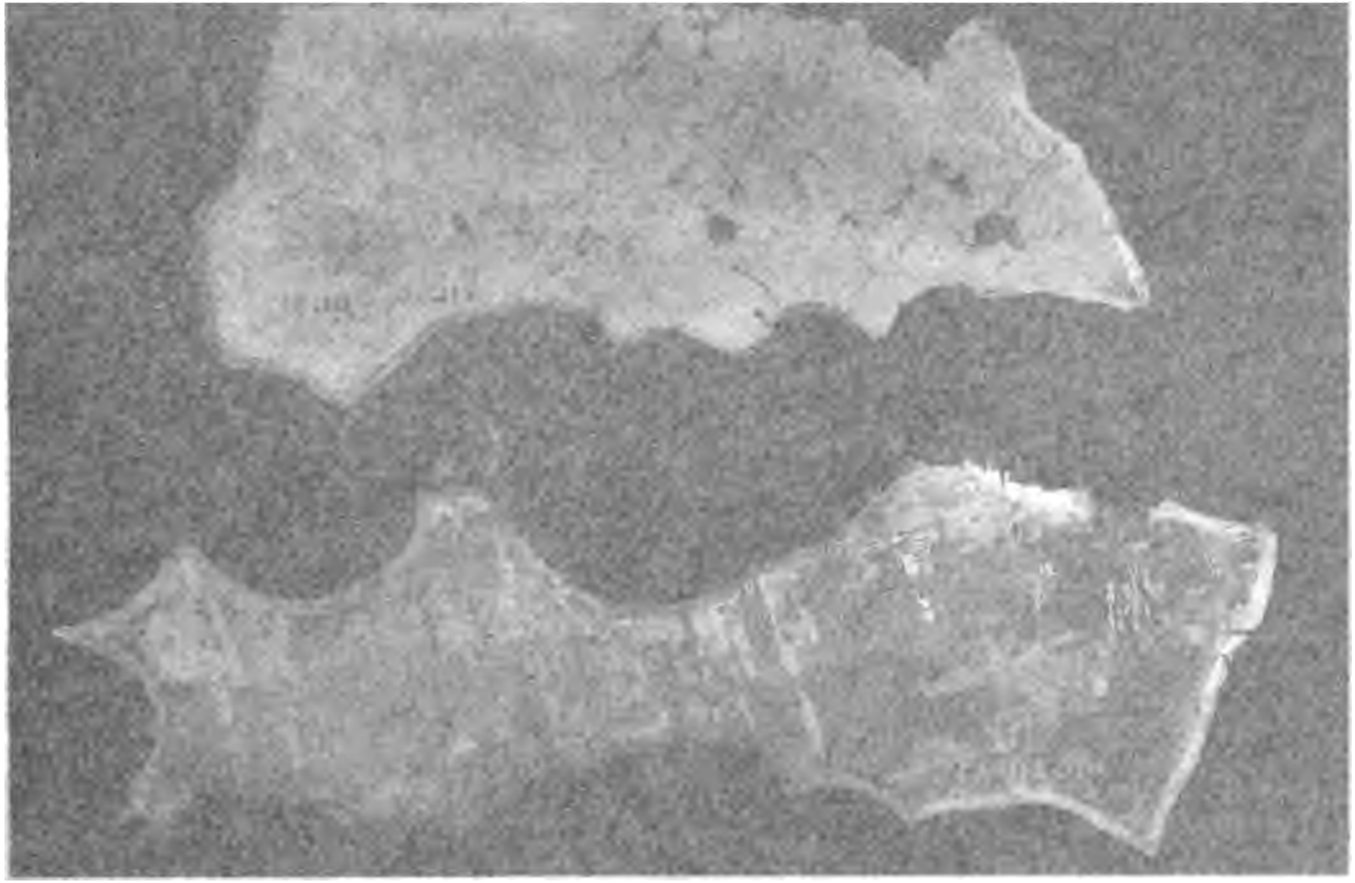
Mount Vernon x ½



Indian Valley x 3/5.

Ste. Genevieve County

Sacramento Mountains x [illegible]



Mungoodi × [illegible]

Yowndegun × [illegible]

FIELD COLUMBIAN MUSEUM
PUBLICATION 78.
GEOLOGICAL SERIES. VOL. II, NO. 3.

ON THE OSTEOLOGY OF NYCTOSAURUS (NYCTODACTYLUS),

WITH NOTES ON

AMERICAN PTEROSAURS.

BY

SAMUEL W. WILLISTON, M.D., PH.D.
Associate Curator, Division of Paleontology
Professor of Paleontology, University of Chicago.

OLIVER CUMMINGS FARRINGTON, PH.D.
Curator of Geology.

CHICAGO, U. S. A.
June 1, 1903.

ON THE OSTEOLOGY OF NYCTOSAURUS (NYCTODACTYLUS), WITH NOTES ON AMERICAN PTEROSAURS.

BY SAMUEL W. WILLISTON.

In previous papers* I have given a summary of the principal characters of the genus *Nyctosaurus*,† with more or less complete descriptions of certain parts of the skeleton. In the present paper I give a more detailed description of the skeleton, based upon the unusually well-preserved and nearly complete specimen collected by Mr. H. T. Martin, together with some remarks upon the relationships and habits of the American pterosaurs, and the description of a new genus and species from the Lower Cretaceous of Kansas.

The specimen herewith described is of unusual importance, as throwing much light upon the structure, not only of the American pterodactyls, but also upon certain characters of the European ones. It is, I believe, for purposes of study the most complete specimen of this order of reptiles now known, comprising as it does nearly every bone in the skeleton, for the most part associated in their natural relations. The specimen now forms a part of the collections of the Field Columbian Museum.

SKULL.

A full description, with illustrations, of the skull has been given in the Journal of Geology, vol. x, 1902, p. 520. I give herewith illustrations of the mandible, not there figured. A careful measurement of the sides of this bone a little in front of the posterior end of the symphysis, where they are the broadest, obtained by measuring each fractured portion, gives a width for each side of twenty-four millimeters. The corresponding width of the palate is twenty-eight millimeters. This would give, as the greatest depth of the mandible, near the end of the symphysis, about twenty millimeters.

---

*Kansas University Quarterly, vol. i, p. 5, 1892.
American Journal of Anatomy, vol. 1, p. 297, 1902.
Journal of Geology, vol. x, p. 520, 1902.
Text Book of Paleontology, Zittel (Eastman), vol. ii, p. 255, f. 361.

†This genus has generally been known as *Nyctodactylus*. (See synonymy beyond.) Marsh changed the name because of the supposed preoccupation of the name *Nyctosaurus*. In this he was not justified. The name has never been used otherwise for a genus of animals. Doubtless he thought the term conflicted with Nyctisauria, used for a group of sauria. It does not, however, according to the accepted canons of nomenclature, and the original name should not be displaced.

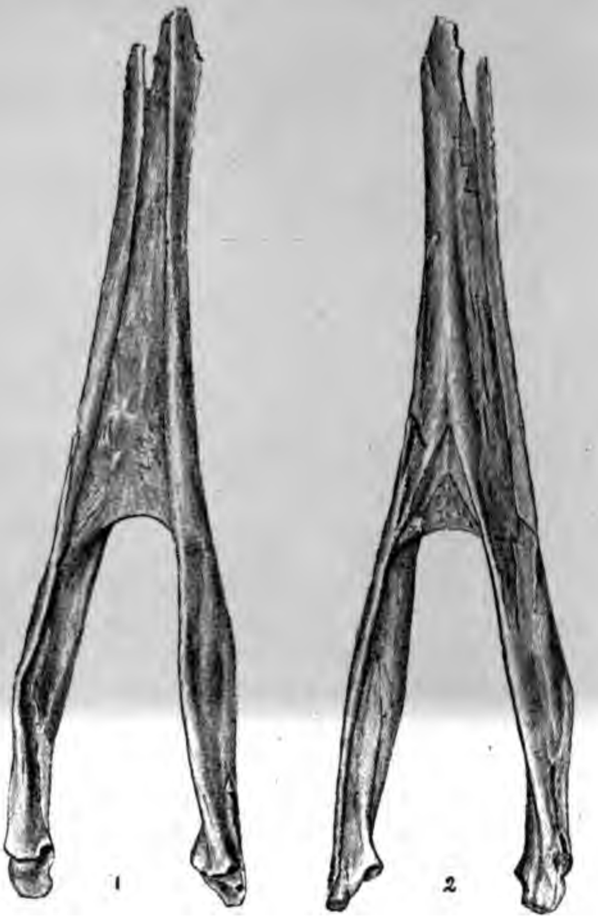


FIG. 1. Mandible of *Nyctosaurus gracilis*, x ⅔. 1, from above; 2, from below.

MEASUREMENTS OF MANDIBLE.

	mm.
Length, as preserved	168
Lengths of rami to hind margin of floor	78
Width between condyles	39

HYOIDS.

Two slender, cylindrical, gently curved bones, about thirty millimeters in length, were found lying side by side beneath the anterior part of the skull. They are sufficiently well shown in Plate I of the paper cited in the Journal of Geology. Lying near the occiput in the same plate, is seen a small, triangular, or V-shaped bone which I then thought might be a proatlas, said by Zittel to occur in the pterodactyls, but of which there is no other evidence in this specimen. Since the removal of this bone from the matrix, it seems quite surely to be, rather, the anterior, median element of the hyoidean apparatus. One view, which I take to be the superior, is shown in Pl. XLI, Fig. 6, three times the natural size, and, in Fig. 7 of the same plate, is shown one of the articular extremities (*a*) from the side, much more enlarged. The bone is nearly flat, with the pointed extremity curved upward, and with the two articular extremities much more massive than the remainder of the bone; they are also directed upward. Each has a smooth, synovial articular surface, doubtless for the articulation of the cylindrical rods. On the opposite surface, near the articulations, there is a slight longitudinal ridge, and near the middle of the bone on each side, there is an elongated, oval surface, apparently for muscular attachment. The slender rods seem to agree quite with the hyoidean bones of other pterodactyls, but I cannot find that the triangular bone has ever been described.

VERTEBRÆ.

Seven has usually been accepted as the number of vertebræ in the neck of pterodactyls. If, however, we consider that vertebra which bears the first rib articulating with the sternum to be the first dorsal, then I believe that the prevailing number of cervicals in pterodactyls is eight. Fürbringer has already expressed the opinion that there are eight vertebræ instead of seven:* "Falls die Patagiosaurier zum Theil nur sieben Halswirbel besitzen, wie algemein behauptet wird, aber meines Erachtens erst noch zu erweisen ist, so wäre eventuell anzunehmen, das dieselben durch eine geringgradige, kranial gerichtete Wanderung der vorderen Extremität ihren ursprünglich aus acht Wirbeln bestehenden Hals um einen in das thorakale Gebiet übergehenden Wirbel verkürzten." He further expressed the opinion that the vertebra which I had considered to be the first dorsal in *Pteranodon* was really the eighth cervical. In a later paper I stated that the eighth vertebra in the neck of *Nyctosaurus* was a functional cervical, though a structural dorsal. . . . I have usually assigned this vertebra to the dorsal series because of its great structural differences from the anterior cervicals; but these differences are scarcely greater than those of the last cervical in the turtles. Owen† correctly located it in the neck. In his description of this vertebra in *Dimorphodon* he says: "At the base of the neck or the beginning of the back, the vertebræ suddenly decrease in length; the hypapophysis disappears, or is represented only by a slight projection of the lower border of the anterior cup; parapophyses [i. e., exapophyses] are less produced. The lower surface of the centrum is flattened and quadrate in form. The parapophysis, diapophysis and rudimental rib coalesce around the vertebrarterial canal; an oblique ridge is continued from the anterior zygapophysis downward and outward upcn the pleurapophysis and behind the zygapophysis. Above these developments the neural arch contracts from before backward to an extent of five lines, compared with a total vertebral breadth anteriorly of one inch, eight lines; it then rapidly expands, rising vertically at its fore part, and developing at its back part the posterior zygapophysis, the articular facets of which look more directly outward than in the long cervical vertebræ; the superincumbent tubercle is more distinct from the facet; the posterior zygapophyses are also much more approximated than in those vertebræ."

---

* Jena. Zeitschr. f. Naturwissenchaft, vol. xxxiv, p. 665, 1900.

† Paleontograph. Soc., 1869, p. 69.

It would seem evident from this description, which applies in the main to the corresponding vertebra of the Kansas forms, that the eighth postcranial vertebra is really a cervical. Certainly we can hardly put a vertebra with rudimentary ribs at the beginning of the dorsal series! Owen afterwards ascribed eight vertebræ to the neck, or seven, counting the united axis and atlas as one. Quenstedt, also, in 1855, gave the number as eight. O. Fraas (Paleontographica, 1878, p. 166) found eight vertebræ in the neck of *Pterodactylus suevicus*, but mistook the third for the axis, thus counting only seven.

In my earliest paper* on *Nyctosaurus* I said: "The centra of twelve vertebræ are preserved from the region back of the neck. Three of these are evidently anterior thoracic, judging from their structure and the position in which they lie. The shortest of them, to which was attached a very large rib, and which was lying in front of the scapula, may represent the first thoracic vertebra." This specimen I have figured in Pl. XLIII, Fig. 7, of the present paper. The specimen is fortunately preserved with little or no distortion, though a part of the spine is wanting. As seen from the front (the view figured), the transverse, shallowly concave cup is straight or gently concave on its upper margin, and convex below. Arising from the front end of the centrum there is, on each side, a very stout parapophysis, with which the head of the rib referred to was in apposition. On the anterior side of this process, and continuous, or nearly so, with the outer side of the cup, there is an oval, convex articular surface for union with the exapophysis. Above this process, separated by a notch, there is a long, flattened diapophysis, for articulation with the well-developed tubercle of the rib. The anterior zygapophyses are much more approximated than in the long cervical verterbræ. Their articular surface is oval, the plane of each nearly at right angles with that of its mate. The spine is broad and transverse; from the front it presents a median ridge. On the under side the centrum is flat, the flatness reaching nearly to the extremity of the parapophysis; the width is considerably greater than the length. The posterior surface of the centrum in this specimen is distinctly roughened for sutural union with the following centrum; the posterior zygapophyses also unite with the succeeding ones suturally. This vertebra is very clearly the first of the notarium, as Seeley has happily called the united dorsal vertebræ. "Two other vertebræ found close by the one described, and possibly one or the other contiguous with it, differ remarkably in having no or a rudamentary parapophysial process, and in having the diapophysis much shorter." "In *Pteranodon* there are at least four vertebræ with dia- and parapophyses." "In two other centra there is a long, recurved, parapophysial process, as though formed by an anchylosed rib, on each side; they are probably lumbar vertebræ." It is very clear, however, that these last two vertebræ are not lumbars, but separated elements of the notarium. Of the two other vertebræ mentioned, one is probably the eighth cervical, described below, while the other may be the fourth dorsal.

---

*Kansas University Quarterly, vol. i, p. 9.

In *Pteranodon*, I thought there might be two vertebræ intervening between the elongated cervicals and the notarium. "The centrum is short and broad, so different from the preceding one that it is possible there may be an intervening one lost. The ball is more than four times as broad as high, concave on the upper margin, convex below. The post-exapophyses are large, and confluent with the articular faces of the ball, but are concave. The convex pre-exapophyses, at the outer side of the cup are at the base of the lower root (that is the parapophysis) of the elongated transverse process."* This vertebra corresponds with the eighth post-cranial vertebra of the present specimen, but an "imperfect vertebra, evidently following the one described, has the centrum very similar, save that the spine appears to be less stout." I cannot at the present time examine this specimen, but it is probable that it is the first separated vertebra of the notarium.

From the foregoing, then, it seems assured that there is a free, short vertebra in front of the notarium, in both *Pteranodon* and *Nyctosaurus*, bearing a free, small rib, which does not unite with the sternum. This vertebra is the eighth cervical, and is probably present in all pterodactyls. It is strange that authors, in the description of the neck bones of the pterodactyls should have so often spoken of the united atlas and axis as one vertebra, thus reckoning seven instead of eight vertebræ in this part of the column. Von Ammon* thus describes the neck vertebræ of *Rhamphorhynchus longicaudatus:*

---

*Williston, Kansas University Quarterly, vol. vi, p. 40.

"Es sind sieben Halswirbel vorhanden. Atlas and Epistropheus werden hierbei als ein Wirbel gerechnet. Beide miteinander zusammenhangen, ihre Gliederung und Form sind undeutlich; die Knochen sind durch spăthige Masse entstellt. Es folgen nun nach rückwarts fünf gleichgestaltete, deutlich von einander abgegrenzte Wirbel, dann kommt (der VII in der Reihe) ein von diesen etwas verschieden aussehender, weil anders gestellte Wirbel der den abschluss des Halses bildet; der unter letzterem befindliche Wirbel (der achte, [in reality the ninth]) besitzt bereits eine grössere Rippe, so dass mit ihm die Reihe der Brustwirbel zu beginnen ist."

Atlas and axis, Pl. XLI, Figs. 3–5. The atlas is coössified with the axis for the most part in the adult specimen, though leaving a distinct sutural line of division in the more immature specimen. In the younger specimen, the coössification is less complete, and the axial intercentrum is also apparent, though indistinguishable in the older specimen. The atlas is composed of the usual number of parts, though the centrum, or odontoid must be small. The intercentrum forms the lower third or more of the cup; it is deeply and smoothly concave, with a sharp cotylar rim, which is nearly semicircular in outline. Its upper border in front has three parts: the middle one, concave in outline, joins the odontoid; the lateral borders, oblique in position, join the bodies of the neurapophyses. The posterior surface is probably flat, or but slightly concave; the sutural line with the axial intercentrum is nearly parallel to the rim, and the width is slight, though a little greater on the ventral side, where the under border slopes somewhat ventrad toward the axial intercentrum.

The bodies of the lateral pieces, or neurapophyses, of the atlas complete the rim of the cup, each forming a little less than one-third of the circumference. Their lower border unites with the atlantal intercentrum; the inner, lower border, joins the odontoid; while the inner, upper border, thinner and less in extent, unites with its mate in the middle. The dorsal processes or arches are slender, somewhat oblique, and but slightly dilated at the distal extremity, which appears to be free. They apparently curve backward, to be applied throughout the whole of their extent, to the thin neural border of the axis. The bottom of the cup is formed by the odontoid. Its anterior surface has three convex borders of nearly equal extent, ending more acutely above. How deep or thin this bone is cannot be said, and it is not impossible that the surface appearing in the cup is really the anterior face of the body of the axis, the odontoid being obsolete. The inner ends of the lateral pieces are thin, and it is impossible to say whether the odontoid appears on the floor of the neural canal or not.

---

* Correspondenzblatt des Naturw. Ver. in Regensburg, 38 Jahrg., 1884, p. 151.

The axial intercentrum is a large, wedge-shaped piece intervening between the atlantal intercentrum and the body of the axis. It is scarcely keeled in the middle below and reaches as high on the sides as does the atlantal intercentrum.

The body of the axis is short and much expanded posteriorly. Its ball is small and widened transversely. Below the ball the body is expanded into a very large, flaring rim, inclosing a deep concavity, having a broad articular surface transversely. This surface evidently corresponds to the united postexapophyses of the later vertebræ—the "posterior parapophyses" of Owen and Plieninger. Nothing quite similar to this structure seems to have been observed in any of the European pterodactyls, though an axis figured by Owen,* as also Seeley, seems to approach this structure. Nor do I find a corresponding adaptation of structure in any of the following vertebræ.

The arch of the axis is broad and relatively high. The neural rim in front, to which are applied the dorsal neurapophyses of the atlas, is thin, forming a heart-shaped opening. The spine is broad, low in front, where there is a thin margin, for a short distance, and is highest behind. The sloping border is thickened, the posterior border thin. Below, on each side, there projects backward a strong process, on the under side of which, before its termination, is the small, oval zygapophysis.

In the figures given in Pl. XLI, I have partially restored the axis and atlas after two specimens, both complete, but compressed in different ways. The length of the atlanto- axis is 14 mm.

Plieninger† describes the atlas in *Pterodactylus kochii* as consisting of a "ziemlich massiven Körper, sowie aus einem Nervenrohr umschliessenden Bogenpaar, welches aussen und oben jederseits einen Fortsatz trägt, der wohl zur Anheftung von Muskeln diente." He also identifies the bone considered by Fraas‡ as a "Schlundring" as the atlas. From the description and figure it would seem that the atlas of *Pterodactylus* is of a very different structure from that in *Nyctosaurus* and *Pteranodon*. (I have seen the united axis and atlas in a species of the latter genus; they resemble the same bones in *Nyctosaurus.*)

Third—seventh cervical vertebræ, Pl. XLIII, Figs. 7–8. The cervical vertebræ were lying close together between the back of the skull and the top of the thorax, but they were dislocated and disassociated, so that nothing can be told of their sequence from their position. Three are lying upon their ventral surface, that is, compressed dorso-ventrally, and two were more or less crushed laterally or obliquely. There is less difference in the lengths of the five following the axis than is the case in *Pteranodon;* I am therefore somewhat in doubt as to the precise position of some of them. Those that are depressed have the under surface irregularly plane or concave, with the lateral margins rounded and concave, formed by the ridge which reaches from the anterior zygapophysis and exapophysis on each side to the corresponding posterior exapophysis. At the front margin there is an oval fossa, or depression, on each side, separated by a convex surface; this convexity seems often to be produced into a distinct hypapophysis in the European pterodactyls. In a previous paper I stated that the exapophyses are non-articular in this genus. This statement, after a more careful examination of the specimens removed from the matrix, I know to be erroneous, at least so far as the processes of the posterior vertebræ are concerned. Owen has identified these processes with the parapophyses, and Plieninger prefers to adopt this name for them. As will be seen by an inspection of Fig. 7, Pl. XLIII, the true parapophysis—that is the process for the articulation of the head of the rib, for which the term was originally introduced by Owen, and in which sense it is now used—is always situated at the anterior end of the vertebra, close to the rim of the cup. This process bears on its anterior face, close to the rim of the cup, a convex, articular surface for union with the corresponding concave surface of the "posterior parapophyses" of the preceding vertebra. One might with as much propriety call these posterior prominent articular processes the diapophyses, or posterior inferior zygapophyses, as "posterior parapophyses." There is no such thing as a posterior parapophysis, nor can there be. Nor could these posterior "parapophyses" ever have arisen as processes for rib articulation. They are very characteristic of the pterodactyl vertebræ, taking the place of the lateral or double articulation of the cryptodire testudinate cervical vertebræ. I have given these articulations a distinctive name of exapophyses in order to save much circumlocution in their description; in any event they should not be called "parapophyses," since they have nothing to do with these processes, either morphologically or functionally.

---

* Brit. Fos. Rept. iv. Pl. viii, fig. 2.

† Paleontographica, 1901, p. 17.

‡ Paleontographica, xxv, Pl. xxii g

The cup and ball are widened transversely; in the depressed specimens very much so, and this is not due to their crushing, since those lying upon their sides, though mutilated, still preserve evidence of a lateral elongation of the articular surface. The convexity of the ball is marked dorso-ventrally, more so near the neural side. The posterior border between the exapophyses is thin and concave, nearly concealing the ball, when seen from below. The anterior zygapophyses project much in front of the cup;

they are widely separated from each other. A ridge extends downward and posteriorly from the outer side of the zygapophysial process to the outer side of the convex exapophysis or parapophysis. I find no foramen inclosed between these processes, and can see no vestige of a cervical rib, such as is described in certain European pterodactyls. The posterior zygapophyses are concave and oblique, and above them, there is a more or less prominent process, a sort of "metapophysis." They do not extend as far back as the ball, leaving a wide space between and back of them in which the floor of the neural canal is visible. The laminæ are broad, thin, and roof-like, meeting in the middle and forming a very thin, neural spine. The length of the base of this spine varies not a little in the different vertebræ, from twelve to sixteen millimeters. In only one vertebra is there a long spine, the one figured in Pl. XLIV, Fig. 17, which I take to be the seventh cervical. In the others, the free, thin border slopes slightly upward and forward, forming a rounded spine but a few millimeters in height.

Eighth cervical vertebra. Pl. XLIII, Fig. 8. The eighth vertebra, which, as already explained, is a real cervical and not a dorsal, was lying close to the first notarial vertebra, and near the presternal process of the sacrum. It has been so much compressed that all of its characters cannot be made out with clearness. A figure of it is given as it lay in the matrix. It differs greatly from the vertebra preceding it in the shortness of its centrum, the character of its spine, and in the presence of diapophyses. The ball is transversely widened, and has, at each extremity, a large, concave, articular exapophysis. The post-zygapophyses are situated much posteriorly to the ball, differing therein remarkably from those of the preceding vertebræ. The spine above the zygapophyses is very short and thick; seen from behind, it is concave, and ends obtusely nearly over the zygapophyses. On each lateral expansion, near the upper extremity, there is an oval, rounded, smooth surface, forming a sort of process corresponding to the "metapophyses" of the earlier vertebræ. The front border of the spine is concave in outline, and is rounded. There is a rather slender and moderately long diapophysis, springing high up on the arch. In the specimen it has been compressed against the vertebra, but seems to end in an articular process. On the under side of the vertebra, near the mutilated diapophysis, there is a fragment of a rib, more slender than those of the notarium, which probably belongs with this vertebra. In the much confused anterior end of this vertebra, there is a small process on each side, evidently the exapophysis, which may also have served for the articulation of the head of the rib; if so, however, the head must have been small. In the specimens of the *Pteranodon* vertebræ already described, this parapophysis seems either rudimentary or wanting. I suspect that the rib was single-headed here. Because of the small size of this rib, the large size of the exapophyses, and the very free union of the vertebra, as also because of the position of the notarium in the specimen, apparently in articulation with the first tubercle of the sternum, I feel confident that this vertebra does not articulate with the sternum, and that it is a cervical.

Plieninger, l. c., considers the eighth shortened vertebra in *Pterodactylus* as the first dorsal, because it bears a diapophysis. No rib was preserved in his specimen, and he does not state whether there is a parapophysial process for the rib. If a rib was present, it was doubtless small, since the next three pairs of ribs are found in place, and are "besonders kräftig." The next three or four pairs are also strong. The posterior ribs are slender.

Dorsal vertebræ. Pl. XLI, Fig. 1; Pl. XLIII, Fig. 7. The three firmly united vertebræ of the notarium, which are visible, lie with their ventral side uppermost, directed a little obliquely toward the left side, and are partly concealed beneath the sternum. The front end lies about ten millimeters back of the front end of the presternal process of the sternum. The first two centra are visible nearly wholly, the third only in part. The centra are flat below, concave on the lateral margins. The first has a concave cup margin, and on each side a stout parapophysis is continued into a strong rib, without clear indications of sutural union. This vertebra in the Kansas University specimen has the ribs free, and it was itself separable from the following centrum through its suture; it is figured in Pl. XLIII, Fig. 7, and has already been described. The parapophysis of the second notarial vertebra seems to be given off somewhat further back, and there are indications of its sutural union with the rib about seven millimeters from the body. The rib is four millimeters in width beyond its proximal part, and a length of about thirty millimeters was preserved. A specimen of a notarial rib, probably the first, preserved with the Kansas University specimen, has a length of forty-five millimeters and a width of five. The corresponding rib in this specimen must have been not less than fifty millimeters in length, and probably about sixty. Whether the third vertebra bears similar anchylosed ribs in this specimen cannot be said, as they are covered by the sternum, but since the third vertebra in the Kansas University specimen has such, it is undoubtedly also the case in this. The end of a flattened rib, about twenty-five millimeters in length and three or four in width, is lying by the articular margin of the sternum, and may belong to this vertebra.

Lying in the axis of the notarium, a convex rim of a dorsal vertebra has partly protruded through the thin sternum. This vertebra is doubtless either in direct articulation with its preceding vertebra, or but very slightly removed. The length of the series is about fifty millimeters, showing that five vertebræ are associated in it, and that the protruding one is the fifth. Whether the fourth and fifth are both suturally united in the notarium cannot be said, but in all probability the fifth at least is free, since its convexity shows it to be of the nature of the following ones, and because one of the small posterior ribs seems to have been articulated with it. The sixth, seventh, eighth, and ninth vertebræ are nearly in relation with each other, behind the sternum, lying upon their dorsal side, but are pushed somewhat to the left. They are cylindrical in cross-section, with smooth, evenly concave sides and inferior border, with a deep cup and a prominent ball. They are a little longer than broad, of nearly equal length, though a little more slender posteriorly. The anterior zygapophyses extend in front of the cup. The elongated and slender diapophyses arise high up on the arch from near the anterior part of the vertebra, and are directed horizontally outward. These vertebræ are quite similar to those of *Pteranodon*, and are doubtless quite like that figured by Seeley in his Dragons of the Air, p. 86, Fig. 26. The last dorsal (or first sacral) (Pl. XLI, Fig. 1, *dv*), the tenth back of the neck, is flat on its inferior surface, and its transverse process I think arises from the centrum as in *Pteranodon*. It is firmly united with the sacrum by suture in both genera, and is quite as properly counted with the sacrum as with the dorsal or lumbar vertebræ. It is probable that its transverse process unites with, or reaches to, the anterior projection of the ilium, as seems also to be the case in *Pteranodon*.

The position in which the skeleton is lying indicates that the right coraco-scapula and the pelvis are in the positions in which they were as regards each other while yet held together by the ligaments. The right arm, falling across the abdomen, has caused a slight dislocation of the dorsal vertebræ, the notarium held by the ribs has been turned somewhat obliquely, and the sternum has settled down a little to the left. The ends of the scapulæ, however, are nearly in the relative position to each other which they must have held during life, and the axis of the sacrum is in line nearly with the presternum.

Now, by bringing all the vertebræ back into a straight line, the ten vertebræ fill the entire space between the neck and the true sacrum, proving almost incontestably that there were neither more nor less than ten, a number found in no other reptiles except the turtles and *Pareiasaurus;* indeed, if we call the last a sacral, then there are fewer presacral vertebræ in *Nyctosaurus* than in any other known reptile.

The sacrum proper, as described below, is composed of six vertebræ, the lines of sutural union of which are clearly visible in the specimen.

Four caudal vertebræ are preserved, lying close to the proximal end of the left femur. The largest of these (Pl. XLIII, Fig. 11), that evidently immediately succeeding the sacrum, is flat at each end, and has neither distinct processes nor zygapophyses, and only a small, low spine on the posterior part; its width posteriorly is much less than that anteriorly. The other three vertebræ are in a series, slightly separated from each other, and are mere nodules of bone, without processes of any kind, about four millimeters in length by three in width; the last one ends in a conical point. From the tapering of the first, and the association of the last three close by the side of the femur it seems very probable that the tail was short and slender.

MEASUREMENTS OF VERTEBRÆ.

	Length, mm.	Width, mm.	Expanse, mm.
Atlanto-axis	14	----	----
Third cervical	24	----	----
Seventh cervical	21	----	----
Eighth cervical (about)	9	----	----
First dorsal	9	11	----
Second dorsal	10	11	----
Third dorsal	10	11	----
Length of first five dorsals (about)	53	----	----
Sixth dorsal	9	8	31
Seventh dorsal	9	8	30
Eighth dorsal	9	7.5	29
Ninth dorsal	9	8	----
Lumbar (tenth)	10	9	32
First true sacral	9	7.5	35
Second sacral	9	7.5	37
Third sacral	7.5	7.5	32
Fourth sacral	7	7	28
Fifth sacral	6	6.5	21
Sixth sacral	6	6.5	15
First caudal, or caudo-sacral	7	10(8)	----
Distal caudals	4, 4, 4,	3, 3, 3	----

RIBS.

Thoracic. Pl. XLI, Fig. 1, *r,r.* There are apparently four pairs of stout ribs arising from the first four dorsal vertebræ, the first three of which, at least, are anchylosed to the centrum in the adult animal. They were doubtless all attached to the four tubercles on each side of the sternum.

Beginning with the fifth dorsal, the ribs are single-headed, and are very slender and delicate. Four pairs are discernible in the specimen, and a fifth seems to be indicated by a fragment. The largest of these, that apparently belonging with the fifth dorsal, is gently curved. It measures about 75 mm. in length, 2 across its somewhat expanded head, .8 across the shaft a little beyond the capitular thickening, and but .4 near its distal extremity. The sixth vertebra has its rib on the left side in relation with the extremity of the diapophysis; it is a little shorter, .75 in width near its proximal extremity, and .3 distally. The seventh also has a rib in relation with the left diaphophysis; it is yet shorter, and nearly straight; measures .6 in width proximally, and .2 distally. The next rib is straight, and yet more slender, and shorter. The tenth vertebra, that connected with the sacrum, I do not think bore a free rib.

In a former paper I stated my belief that the slender, posterior, single-headed ribs did not inclose the abdominal cavity, but were directed more or less outwardly in the patagial membrane. In support of this belief it is seen that all these ribs are remarkably slender, and but slightly if at all curved. Their free and loose connection with the vertebræ, and their delicacy prevented them from being of use as a support to the abdominal contents; certainly not if the animal walked in a quadrupedal position. Furthermore, if they extended in the walls of the abdomen, the abdomen must have been exceedingly voluminous, and widely unprotected in front.

A better support for my contention is afforded by the position of the various bones in this specimen as they are preserved. All these ribs lie directed outwardly or obliquely backward, and none of them are mutilated or broken in the least, save as may have happened in the preparation of the specimen. The right arm lies obliquely across the abdomen; it was evidently sustained by the soft parts until after the ligaments connecting the forearm bones had partly decomposed, since these two bones and the carpals only are slightly disassociated from the remainder of the wing bones. The radius and ulna fell to the back part of the abdominal cavity while yet the pelvis was held together, permitting the left innominate bone to fall outward over the end of the ulna and carpal. Furthermore, the ventral ribs have fallen upon the radius. Now, under these conditions, had the ribs curved forward in the abdominal walls to meet the ventral ribs, they surely would have been entangled and doubled up beneath the forearm. But this is not at all the case, and it seems highly improbable that the fleshy walls of the abdomen could have fallen apart, and spread out laterally with the wing folded across them. From all of which evidence, I believe that the ribs were directed laterally, supporting the patagial membrane, perhaps as in *Draco*, and that they did not inclose the abdominal cavity.

Further evidence of the same tenor is furnished by the type specimen of ***Rhamphorhynchus phyllurus*** Marsh, which I have recently examined. In this specimen, the right arm had also fallen across the abdomen, while yet having the patagial membrane attached to it. Nevertheless, the very slender ribs are spread outwardly, and were not doubled up below the wing bones. They cannot be ventral ribs, since these are large and broad in this species of *Rhamphorhynchus*, according to Zittel.

In *Pterodactylus spectabilis*, as figured in the books, a number of very delicate abdominal ribs are shown, as depicted by Von Meyer. "An die unteren Hälfte des Rumpfes kommen fünf fadenförmige Abdominalrippen. Sie sind fadenförmige, ohne sich gegen die Mitte her zu verstarken, und bei ihre Länge und dünnen Beschaffenheit etwas verbogen. Die erste Rippe, die längste, ergiebt 0.026."* Is it possible that the abdominal and vertebral ribs have been confused in this description?

Ventral ribs or *parasternum*. Pl. XLI, Fig. 2. The ventral ribs were, for the most part, lying in position nearly contiguous with the xiphisternal process. There appear to be four pairs, the first three lying together and united. The first pair is somewhat uncertainly shown, broken on the left side and partly concealed on the right below the border of the sternum. The second pair is very distinct. They are somewhat V-shaped, co-ossified and thickened in the middle, and terminating outwardly in a slender point. The third pair was in position, co-ossified with the margins of the second pair, but not united in the middle. Another pair is seen by the right side of the tenth vertebra, partly beneath the ulna; their whole form cannot be made out, but they are wider and longer, apparently, than the third pair, to which they could have had no ossific union. These ribs are all thin. In the restoration it seems evident that the last pair of these ribs would approach, if not actually meet at their ends, the anterior ends of the prepubic processes. I am very much inclined to believe that the prepubis is really not a part of the pelvis, but rather a part of the parasternal ossifications.

One of the best descriptions extant of the ribs of pterodactyls is that of von Ammon (op. ct.):

"Die hintersten dreizehnte Rippe stellt einen zarten Knochenstreifen vor. Das untere Ende der Rippen ist verdickt und bildet ein kleines Gelenkköpfchen, an welchem der obertste Theil einer Gürtelrippe der Bauchwand befestigt ist. . . . Durch ihre Verbindungen [d. h. der Abdominalrippen] mit den oberen Rippen bestehen also vollständige Gürtel in der Bauchwand. Es schliessen sich immer zwei Bauchrippen zu einem formlichen Halbkreis zusammen. Am Vereiningungspunkte ist eine mediane Verdickung vorhanden, die eine nach unten Spitz auslaufendes langes Köpfchen bildet." The ventral ribs of this pterodactyl (*Rhamphorhynchus longicaudatus*) are very thin and simple, in contrast with the broad ventral ribs of the larger forms of *Rhamphorhynchus*, according to Zittel.

---

* Paleontographica, vol. x, p. 4, 1868.

Owen* says that "the ribs of *Dimorphodon* acquire a characteristic tenuity beyond the sixth pair," and Seeley mentions the fact that the posterior ribs of the pterodactyls are slender. In current restorations of the pterodactyls, the posterior ribs are often shown as long and strong bones, inclosing a large and deep abdomen, the outlet of which must have been through the narrow pelvis. It has been suspected that there are sternal ribs intervening between the vertebral ribs and the sternum, but there is no evidence of such in the present specimen.

PECTORAL GIRDLE AND EXTREMITY.

So far as is definitely known, the pectoral girdle comprises the sternum, coracoid and scapula only. No clavicles (unless the ossification hereinafter described is a clavicle), inter-clavicle, epicoracoids, or precoracoids, even, are known. Furthermore, the bones present are so strangely modified that they present very little resemblance to the same elements in other reptiles, agreeing rather better with those of birds, an agreement, however, that I believe to be homoplastic in nature.

Sternum. Pl. XLII, Fig. 1. The sternum is a broad and thin bone, with a stout anterior projection, and a thin, spatulate xiphisternal process posteriorly. The presternal process is narrowed and rounded on the under surface, and may have projected somewhat ventrad. The saddle-shaped articular surfaces for the coracoids look dorsad and laterad. The anterior borders at the sides of the presternal projection are thickened, concave slightly in outline on the inner part, straight and more oblique on the outer ends. The lateral margins are thin, and are nearly parallel with the median axis of the bone. These borders have three emarginations, separated by four rounded projections, the anterior one longer and thicker than the others, which are thin and small. The posterior border is convex on either side, ending in a short and deep concavity at each side of the flat xiphisternal process. This process is spatulate, with the distal end rounded or very slightly emarginate, and doubless gave attachment to the series of abdominal ribs, which lie in the specimen nearly in connection with it. The sternum is somewhat thickened in the middle anteriorly, or back of the base of the anterior process. On the sides and behind the bone is very thin, almost paper-like; this thinner part in the specimen shows numerous small crinkly fractures, doubtless caused by the flattening of the concave bone; similar crinkles are visible in the thin prepubic bones. The sternum lies nearly in its normal position in the skeleton. In falling backward it has been displaced a little obliquely to the long axis of the body, as have the dorsal vertebræ, perhaps caused by the weight of the right arm lying across the body. The presternal process extends about half an inch in front of the notarium.

---

* Paleontographica Soc., 1869, p. 69.

MEASUREMENTS OF STERNUM.

	mm.
Length in middle	88
Greatest width, across attachments of first rib	80
Length of rib margins	28
Width at coracoidal articulations	40
Length of presternal process in front of coracoids	16
Width of xiphisternal process	9
Length of xiphisternal process	11

Coraco-scapula. Pl. XLIII, Fig. 6. This conjoined element is a moderately stout, U-shaped bone, with the coracoid branch stouter and a little longer than the scapular. The distal extremity of the scapula is slightly expanded and flattened spatulate; the shaft is flattened and somewhat constricted in width. There is a rounded protuberance on the outer or upper margin, just beyond the glenoid rim, for the attachment of muscles. This process appears to be wanting in the specimen previously described by me of this genus, but it is possible its absence is due to some postmortem compression. The glenoid articulation is deeply concave from above downward, convex from side to side, and is bounded both above and below by a prominent ridge, that on the inferior border being much stronger than the upper one. The glenoid surface is placed obliquely to the shaft of the bones, doubtless in life looking outward and somewhat backward. The surface, from side to side, is narrower below than above. A line indicating the sutural union of the two bones passes directly through the middle of the articular surface transversely. At the bottom of the U formed by the conjoined bones there is a process, rather slender, arising from the inner surface of the scapula, and reaching to the inner face of the coracoid, which it joins. It incloses a small foramen between it and the coracoid, back of and below the glenoid surface. A precisely similar process is found in the coraco-scapula of *Pteranodon*, and in neither genus does the suture dividing the coracoid from the scapula cross this process; it is, apparently without doubt, either a separate ossification joined to the two bones, or else a process from the scapula. I cannot at present examine the under surface of this scapula, and have none of *Pteranodon* for comparison. In *Nyctosaurus*, however, the process seems to be separated from the scapula throughout a large part of its extent. If it really belongs with the scapula, the inclosed foramen cannot be the usual supracoracoid foramen of the reptilian coracoid.

A similar foramen, though of larger size, is shown by Owen in the coraco-scapula of *Ornithocheirus sedgwicki* (Paleontograph., 1857), which he calls doubtfully a pneumatic foramen. Whether the part is an acromion process of the scapula, or possibly a vestigial clavicle, must be left for future research.

The coracoid has a flattened shaft, oval in cross-section near its middle, and flattened at either extremity. The sternal articular surface is convex in its greater diameter, gently concave in the opposite direction. Near the outer extremity of the shaft, on the inferior border, there is a strong process, gradually arising from the shaft but with a deep concavity between it and the articular rim. A small sesamoid ossicle was found lying near it. The shaft at its middle is narrowed and smooth; it seems to lack the strong muscular rugosity on the external part which occurs in the *Pteranodon* coracoid; the process on the outer inferior border is also larger than in *Pteranodon*. It will be observed also in the figure that the glenoid articular surface does not extend to the inferior margin of the coracoid, resembling in this respect somewhat the European forms of this bone. The scapula of course differs markedly from that of *Pteranodon* in the non-articular distal end.

MEASUREMENTS OF CORACO-SCAPULA.

	mm.
Extent of coraco-sternal articulation	10
Least width of shaft, below middle of coracoid	7
Length of coracoid	55
Dorso-ventral diameter of glenoid surface	19
Length of scapula	49
Least width of shaft of scapula	14
Width at distal extremity	16

Humerus. Pl. XLII, Fig. 7. The humeri both lie with the inner side uppermost. The proximal articular surface is distinctly saddle-shaped, the convexity directed from behind forward and inward. The curve of the concavity is greater than that of the convexity in the specimen. The ulnar or median process is very stout, reaching as high as the articular surface. It is broad above, with apparently two faces for muscular attachment, separated by a narrow, free space. Its rounded distal border sinks into the surface of the shaft at about its middle third. The deltoid, radial, or lateral process is very large. It is directed forward and a little downward, its lower margin uniting with the shaft at about the middle third. Both upper and lower borders are deeply concave, the upper one the longer. Its distal extremity is expanded, and has an evenly convex border from above downward. Near the upper end of this border, on the inner side, there is a small, oval, oblique surface, looking inward, for muscular attachment; and, beginning near the middle of the upper border, there is a slender, but well-marked ridge, also for muscular attachment, traversing the anterior face obliquely, and terminating near the lower, outer angle of the process. Fürbringer says of these processes in the pterosaurs: "Proc. lateralis und Proc. medialis, namentlich aber der erstere sind sehr kräftig entwickelt und prominieren insbesondere proximal so stark, dass das zwischen ihnen befindliche Caputhumeri sogar theilweise gegen sich zurücktreten kann; dagegen ist—sehr im Unterschiede zu den meisten Sauropsiden, namentlich aber den Theromorphen und Dinosauriern—der Proc. lateralis wenig in die Länge entwickelt, indem er gewöhnlich nur das proximal ¼ bis ⅓ des Humerus einnimmt. Diese Konfigurationen lassen darauf schliessen, dass die Mm. supracoracoideus (supracoracoscapularis, scapulohumeralis posterior und subcoracoscapularis) eine relativ hohe Entfaltung besassen, der M. pectoralis dagegen keine so abnorme Stärke darbot, wie es von vornherein von einem fliegenden Thiere erwartet werden konnte, und der M. deltoides nur mittelstark entwickelt war."[*]

The shaft below the lateral process is of nearly uniform width. A little above the middle of each bone, on the inner or ventrolateral side, starting from precisely the same place, and lying transversely, there is a slender bone, less than a millimeter in width, and about twelve millimeters in length, preserved. I do not know what it is, nor whether it really belongs in this position, though the similarity of the bone on the two sides suggests that it does. It may be an ossified tendon. . . Because of the position in which both humeri are lying, the distal extremity has been transversely compressed, effacing the articular surfaces to a great extent. There seems to be a small depression on the inner epicondyle.

MEASUREMENTS OF HUMERUS.	mm.
Length	87
Least width of shaft	5
Least width of lateral process	17
Width of lateral process distally	25
Width of humerus through lateral process	42
Width of median process	5

Ulna. Pl. XLII, Fig. 2. The bones of the left forearm lie nearly in position, and in contact with the distal end of the humerus; those of the right side have been slightly separated, the radius detached and removed proximally. The left ulna is lying nearly upon its outer side, partly overlapping the radius; that of the right forearm has been compressed dorsoventrally. The bone is slightly expanded at the extremities. There are two, nearly confluent, articular surfaces at the proximal end, the smaller, nearly circular one, on the inner side, nearly confluent with the large, less deeply concave surface on the inner side. Just in front of this, near the middle of the bone, transversely, there is a pneumatic foramen on the flexor side. The inner side of the bone, at this extremity is expanded into a thin, convex process. The articulation at the distal extremity cannot be made out, as it is largely concealed by the carpals. The shaft is nearly straight, curved forward gently at the distal extremity.

---

[*] Jenas. Zeitschrift, 1900, p. 363.

MEASUREMENTS.

	mm.
Length	144
Width of proximal extremity	44
Width of shaft	24

Radius. Pl. XLI, Fig. 2, Pl. I. The radius is a more slender and slightly shorter bone than the ulna. On the left side it lies partly concealed beneath the ulna and there would seem to have been no pronation of the bone. The bone is more slender than the radius, somewhat concave along its inner or upper border as it lies in relation with the ulna; nearly straight as it lies compressed from above downward. The bone is more expanded distally than proximally. The proximal articular surface is rounded and concave. Lying near the roughened distal surface shown in the figure there was a small sesamoid bone.

MEASUREMENTS OF RADIUS.

	mm.
Length	140
Width of shaft middle third	18
Width distal extremity	24

Carpals. Pl. XLII, Figs. 2, *cd*, 3, Pl. XLIV, Fig. 8. The two chief carpals of the left wrist are in relation with each other and the wing metacarpal, and but slightly displaced from the forearm bones. On the right side they are separated, and the proximal one is partly concealed beneath the ischium, the distal one having its proximal surface obliquely exposed. In the figure (Pl. XLIV, Fig. 10), the one shown obliquely is that of the other carpus figured. The wing metacarpal of the left side (Pl. XLIV, Fig. 2), lying articulated with the distal carpal, has the under side uppermost, from which it would appear that the view given is of the anterior side of the carpus. The proximal carpal is much the larger, extending on the under side either to articulate with the metacarpal, or nearly so. A subangular space is left between the two bones on the radial side, for the articulation of the lateral carpal or metacarpal of the first digit. This latter bone, of the right side, is shown in Pl. XLII, Fig. 3. It is a small, elongate bone, with an articular emargination on one side, which I had supposed was for the pteroid. I give, also, a good figure of this bone of *Pteranodon*, copied from Cope (Cretaceous Vertebrata, Plate VII, Fig. 3). It resembles that of *Nyctosaurus*, though having a less elongated process beyond the articular lateral emargination. The figures of the carpal bones of *Ornithocheirus* given by Seeley (Ann. Mag. Nat. Hist. Aug. 1870, and Dragons of the Air, p. 124) closely resemble these bones. Professor Seeley says of the "lateral carpal": "It is a flat, oblong bone, attached to the inner side of the distal carpal, and, instead of being prolonged distally in the same direction as the other metacarpal bones, is turned round and directed upward, so that its upper edge is flush with the base of the radius, and gives attachment to the pteroid." I had supposed that the larger end, as shown in the present figure, fitted into the interval between the two carpals, and that the emargination was for the articulation of the rounded head of the pteroid, though perhaps the position assigned to it by Seeley is the correct one. The bone is thin on the sides shown in the figure, so that the articulation of the pteroid must have been either in the emargination or with the broader end. Marsh says* that it "stands nearly at right angles with the wrist," and I am inclined to think he was right. The structure of these wrist bones is almost identical with what it is in *Pteranodon*.

MEASUREMENTS OF CARPAL BONES.

	mm.
Length of articulated carpus	15
Greatest diameter of distal carpal	24
Lesser diameter of same	14
Greatest diameter of proximal carpal	26
Length of "lateral carpal"	17
Width of same	8

Metacarpals. The first metacarpal, or pteroid (Pl. XLII, Figs. 4, 5), is an elongated, pointed, styliform bone, with an enlarged articular carpal extremity. In both arms this bone has been displaced, though so closely associated with the corresponding extremity that the position is assured. Its articular end is broad, its margin nearly at right angles with the long axis of the bone. The articular surface is nearly at right angles with the transverse diameter, in life nearly circular in outline, and decidedly convex. It is separated from the bone by a slight constriction. The dorsal border of the bone is very gently concave throughout, and the inferior border is correspondingly convex for the greater part of its extent. The pteroid of the right arm is lying close to the lateral carpal, as though its articular surface fitted into the lateral emargination of that bone in life. Oscar Fraas was the first, so far as I can learn, to recognize the real nature of this bone as belonging to the first digit,† a view afterwards adopted by Marsh and Zittel.

---

*Amer. Journ. Sci., 1882, p. 255.

†Paleontographica, 1878, p. 170.

MEASUREMENTS OF PTEROID.

	mm.
Length	104
Greatest width (at proximal end)	15
Diameter of articular surface	8

The next three metacarpals are, for the most part, wanting in this specimen, a single complete one lying near the distal extremity of the right wing metacarpal (Pl. XLII, Fig. 6). It is a very small, splint-like and slightly curved, pointed bone, measuring about twenty-four millimeters in length by two in greatest width. Its resemblance to the corresponding metacarpals of *Pteranodon* is so great that the whole structure of the hand is doubtless the same in the two genera. I give herewith a diagrammatic figure of these parts in *Pteranodon*, based on a specimen in which nearly all the bones were present and in position, some of the terminal phalanges only being misplaced, and one or two of the fourth finger missing. In a former paper I stated that the phalanges of the hand were of two kinds, long and short. Possibly this is the case in some of the smaller species, but I think not. I doubt not that the small phalanges there described were from the foot, and had become displaced and associated with the hand phalanges in the specimen described.

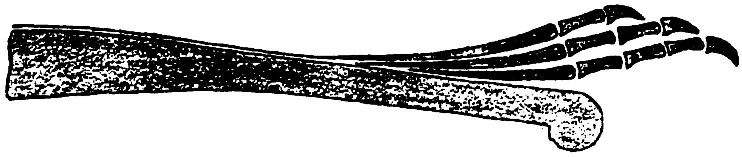


FIG. 2. Metacarpals of *Pteranodon ingens*.

In the specimen of *Pteranodon* the small metacarpals seemed to lie, not as they are diagrammatically figured, one above the other, but more side by side. The second metacarpal is continued, as already stated by Marsh, to the carpus, as a thin, thread-like bone. It was not continued along the dorsal side of the bone, but seems to pass to the radial side, where it belongs. From this it seems also probable that the position of all three bones in life was along the radial dorsal margin of the fifth metacarpal.

Both of the wing metacarpals (Pl. XLIV, Fig. 2) lie upon the dorsal surface, a position in which they are seldom found. The bone is much broader at the base, tapering to beyond the middle, whence the shaft has nearly parallel sides. The proximal articular surface cannot be made out, though there appears to be a division into two facets. The condyles, as in *Pteranodon*, are placed obliquely, the posterior one the larger.

MEASUREMENTS.

	mm.
Length	224
Width at proximal end	18, 23
Width of shaft at middle	11, 12

First phalange of wing finger. Pl. XLIV, Fig. 1. The first phalange, as usual, lies upon the side in both wings. As in *Pteranodon*, it is the longest bone of the body. Its under margin is concave throughout, the concavity greater near each end. The proximal expanded extremity has a deep articular concavity, extending through an arc of about one-third of a circle, with its radius directed at an angle about 45° with the long axis. The upper, olecranon-like projection has a marked emargination of the border above, between which and the proximal end the convexity is greater, with the corresponding deeper concavity of the under border.

There are two articular facets, separated by a median ridge, which fits into the trochlear depression of the metacarpal. The posterior surface extends throughout the whole length of the arc, while that on the anterior side reaches but little more than one-half of the distance, and its upper part is narrower than is the other surface. The pneumatic foramen is on the anterior side, just beyond the end of the articular surface. The dorsal border of the bone is gently and evenly convex from a little beyond the proximal extremity, and the width on the distal three-fifths is nearly uniform. The distal extremity of the bone is curved downward; the articular surface in life was doubtless a vertical oval.

MEASUREMENTS.

	mm.
Length	283
Greatest width at proximal end	27
Chord of proximal articulation	17
Width of shaft, proximal third	14
Width of shaft, distal third	14
Width distal extremity	18
Thickness of shaft at middle as compressed	1.7

The *second wing phalange* (Pl. XLIV, Fig. 5) lies in position in the right wing, but is somewhat displaced in the left. It is much smaller and more slender than the first phalange. Its proximal border is nearly straight and transverse to the axis of the shaft; it is much broader than the shaft. The under border of the bone is gently concave throughout, except on the proximal part, where the concavity is deeper. The upper border, gently concave at the proximal end, is nearly straight thence to near the extremity. The distal extremity is quite like that of the first phalange, though smaller.

MEASUREMENTS.

	mm.
Length	211
Width proximal extremity	17, 18
Width at proximal third	9, 10
Width at distal third	8, 9
Width of distal end	9, 10

The *third phalange* has the proximal extremity preserved, compressed from above. The surface seems to have been only slightly concave. This phalange, like the preceding one, seems to have been proportionally more slender than in *Pteranodon.*

PELVIC GIRDLE AND EXTREMITY.

Pelvis. Pl. XLI, Fig. 1. The pelvis lies with the bones nearly in position, the sacrum with its ventral surface uppermost, the innominate bones separated at their sutures and in juxtaposition with the sacrum, the visceral surface also uppermost.

There was in the sacrum (Pl. XLI, Fig. 1, *s*) in life evidently a considerable concavity transversely, and possibly a slight concavity longitudinally. It is composed of six firmly united vertebræ, the sutural lines between the centra clearly distinguishable. The vertebræ decrease in length from the first to the fifth; the sixth is slightly longer than its predecessor. The centra are flattened in the preserved specimen, though possibly in life they may have been slightly convex transversely. The sacral ribs show no indications of sutural connections anywhere, and are broadly united distally. Between them the oval foramina decrease rapidly in size, and slightly approach the middle line, the last, that between the fifth and sixth vertebræ, being almost punctiform, while the first is of considerable size.

The first process is broad, with a broad, oblique surface, terminating distally in a free, rounded margin. The pelvic brim is indicated by an angular line passing outward and downward obliquely to the upper border of the articular surface for the innominate bone. This surface is oval, and encroaches obliquely on the front surface of the sacrum; beyond it the thin margin of the sacrum does not present a sutural surface on the ventral side. The lateral margins approach each other until at the hind border the distance between them is less than half that at the brim of the pelvis.

The ***ilium*** (Pl. XLI, Fig. 1, *il*) has a long, flattened or somewhat prismatic anterior process, reaching as far forward as the second presacral vertebra. The process is apparently curved somewhat backward in life, and also outward; it has an obtuse anterior extremity. Posteriorly the ilium extends a short distance beyond the end of the sacrum as a short, obtuse process. It sends an angular expansion upward and inward opposite the end of the sixth sacral vertebra, which extends five or six millimeters above the margin of the sacrum, possibly forming a sort of roof over the last sacral and the first caudal, and approaching, or possibly meeting, its mate in the middle. The flattened or ventral portion (Pl. XLI, Fig. 1, *ip*) of the ischio-pubis is somewhat trapezoidal in shape with the symphysial line slightly oblique to the sacral border. Both bones, separated at the median suture, lie with the visceral surface uppermost, and both present a considerable concavity. The anterior border begins at the upper margin of the process, which articulates with the sutural surface described on the lateral margins of the sacrum opposite the first intercostal foramen. The margin is thin and concave as far as the angular process for the attachment of the prepubis. This process is everted from the brim of the pelvis, and is tipped with a small, oval, cartilaginous or articular surface. From this surface the margin, somewhat thicker, recedes in a straight line to the beginning of the median symphysis. The symphysial margin is thin and nearly straight. For the first fourth of its length it seems to meet its mate, if at all, in an harmonious suture, and the symphysis in front may have been somewhat rounded or subangular; beyond this, however, the two bones meet in a very oblique surface, attaining a width of four or five millimeters posteriorly, and the two bones must have formed a thin and sharp keel when conjoined. The posterior border is somewhat thicker than the anterior one. It begins in a rather acute rounded angle at the base of the posterior process of the ilium, and is directed backward and ventrad to the angular extremity of the symphysis. The large rounded ischiadic (obturator) foramen is situated in front of the middle of the bone, almost directly ventrad to the acetabulum; its borders are smooth and thin. Between this foramen and the margin of the ilium, there is a considerable convexity, representing the floor of the acetabulum. Its dorsal margin must be nearly over the line of the sacrum. The junction of the innominate with the sacrum is by a narrow concave sutural surface, fitting on the margin of the sacrum; in front there is a considerable oval surface on the anterior part of the bone, which fits into the depressed surface already described, on the sides of the sacrum. Posteriorly, also, the projection of the ilium has a little broader attachment. Dorsad to this junction the ilium seems to have projected beyond the margin of the sacrum slightly in the middle, expanding in the angular process already described.

Prepubes. Pl. XLI, Fig. 1, *pp*. The prepubes are very nearly as they are in *Pteranodon*, consisting of a flat, transverse ribbon-like band meeting in a somewhat angularly expanded median symphysis, which is thoroughly co-ossified, and with an anteriorly directed, somewhat divergent, flat, and obtusely pointed anterior process at each side, the continuation of the posterior flattened portion which joins the pectineal process on the everted margin of the pelvis. This process is somewhat thickened at its posterior extremity, and is of about the same width as the other parts of the bone. The bone in the specimen had been torn apart at the symphysis, each half remaining in partial juxtaposition with the corresponding half of the pelvis. As flattened out the conjoined bone is much too wide transversely to articulate with the surfaces on the margin of the pelvis; too wide even in the flattened-out position of these parts. It seems certain that the extremities must have articulated with the processes described, quite as I have already described the conditions in the pelvis of *Pteranodon*, and it therefore follows that the bone in life must have had a considerable convexity, in a broad, U-shaped form.

There are no indications of any sutural connection in the bones of the pelvis, except such as I have described with the sacrum and between the two halves. Nevertheless, the presence of the large foramen, the general shape of the bone and the position of the acetabulam would be as one would expect were there really the three elements present. A suture between the ischium and pubis is scarcely to be expected, in consideration of the obliteration of the sutures elsewhere in the skeleton. I am therefore inclined to look with favor upon the view, long held by Seeley, that the pelvis is of the normal reptilian structure, and that the bones in front really do not belong to it. It seems very probable that the anterior prolongations of the prepubes come in contact with the posterior ends of the parasternum, and that the whole bone is merely a continuation of the abdominal armature. However, I must admit that the persistence of the sacral and symphysial sutures, permitting the pelvis to drop apart without distortion, and the utter obliteration of any ischio-pubic suture is inexplicable.

"Naturalists have been uncertain as to the number of bones in the pelvis of pterodactyls, because the bones blend together early in life, as in birds. Some follow the Amphibian nomenclature, and unite the ischium and pubis into one bone, which is then termed ischium, when the prepubis is termed the pubis, and regarded as removed from the acetabulum. There is no ground for this interpretation, for the sutures are clear between the three pelvic bones in the acetabulum in some specimens, like *Cycnorphamphus Fraasii*, from Solenhofen and some examples of *Ornithocheirus* from the Cambridge Greensand."*

By modeling in cardboard and clay the bones of the pelvis and

*Seeley, Dragons of the Air, p. 94.

uniting them in a complete basin, with the necessary curvatures, it transpires that the opening of the pelvis had a diameter of about seven-eighths of an inch, while the outlet could have measured but a trifle more than half an inch.

Femur. Pl. XLIII, Figs. 4, 5. Both femora are preserved, separated by a short distance from the pelvis. The neck is directed upward and at a slight angle inward; it is cylindrical, the head only a little dilated and with its convexity only a little oblique to the axis of the bone; that is, the plane of the rim is nearly, but not quite, rectangular to the axis of the shaft. The trochanter stands a little to the outer side of the middle axis of the bone. From its upper angle a ridged process runs backward for a short distance, to the inner side of which, a little below the free, upper concave margin of bone, there is a small pneumatic opening. On the outer side, the margin of the shaft is convex for a short distance, and is then concave throughout to the extremity. On the inner side above, the margin is correspondingly concave; below this to the condyle it is convex. The upper part of the bone was evidently, in life, nearly cylindrical; below it seems to have been wider and somewhat flattened. Near the middle behind, beginning a little above the condylar surface, there is a narrow, elongated, longitudinal ridge for the attachment of a muscle. The distal articular surface cannot be clearly made out in the crushed specimens. The bone had in life, apparently, a marked anterior curvature, as in *Pteranodon*.

MEASUREMENTS OF FEMUR.

	mm.
Length	81
Diameter of neck	6
Diameter of shaft, upper third	7
Diameter through condyles as crushed	13

Femur of *Pteranodon ingens* Marsh, Pl. XLIII, Figs. 1–3. The convexity of the head is regular, covering nearly half of a circle transversely, probably a little less in the conjugate diameter, the surface thus forming an oval or ovate figure, the plane of whose base is nearly at right angles to the long diameter of the bone. The convex surface is sharply limited from the neck. The neck is cylindrical, rather stout, and is directed nearly vertically downward. The rounded and moderately prominent trochanter is placed over the middle of the shaft, descending into the concavity at the side of the neck, and externally separated from the margin of the bone. The shaft is nearly of equal width throughout; doubtless in life it was nearly cylindrical, with a strong anterior curvature, and a flattening in the popliteal region. The sharp margin of the inner condyle encompasses nearly half a circle. The outer condyle, though extending further, is much less in extent. The inner distal articular surface is the larger, and is separated from the inner surface by a distinct ridge, especially posteriorly.

Tibia. Pl. XLIV, Fig. 3. The tibia is a slender, straight bone, moderately expanded at the upper extremity. The margin of the articular surface above is nearly transverse to the longitudinal axis. The width contracts chiefly at the expense of the posterior margin to the lower part of the upper fourth of the bone, the shaft below being of nearly uniform width. The trochlear surface at the distal extremity is pulley-shaped, covering about half of a circle, perhaps more, and has a moderately deep groove. The sutural union between the tibia proper and the proximal tarsal bone, or bones, is entirely obliterated. The bones of the two sides are compressed in different positions, the left one from the side, the right one from nearly in front; the width above is considerably greater in the former than in the latter, indicating but comparatively little expansion of the upper part from side to side.

There is no trace of any fibula, either in the preserved remains or in any tibial articulation.

MEASUREMENTS OF TIBIA.

	mm.
Length	133 (132)
Width above	15 (11)
Width of shaft at upper end of middle third	7 (6)
Width, lower third	6 (6)
Antero-posterior diameter of trochlea	6 (6)

Foot. But a single metatarsal and one phalange are present in this specimen. These, however, agree so well with the corresponding bones of *Pteranodon* that I doubt not the foot was quite similar to that of the former genus. This metatarsal is expanded at its proximal end and gently convex on the trochlear end. It measures 35 mm. in length, 2 mm. in width at the upper fourth and 4 mm. at either extremity. The bone is compressed from side to side. The phalange, flattened on the side, has a length of 14 mm. The distal end has the extremity convex, its chord rectangular to the long axis of the bone; its width is 3 mm. The proximal end is truncated or gently concave; its width is about 4 mm. The shaft in the middle is scarcely narrowed from the proximal end. I repeat here, briefly, the description of the foot of *Pteranodon*, from my paper in the Kansas University Quarterly, vol. vi, page 50, with some changes.

The first four metatarsals are very slender, straight, and contiguous with each other, each having a flattened proximal articular surface and a rounded trochlear distal extremity. The metatarsal of the fifth toe is rudimentary, subtriangular in shape, with the obtusely pointed distal part curved, altogether resembling an obtuse claw. The first toe has a single phalange, which is long, cylindrical, gently curved, and obtusely pointed. The second toe has two phalanges, the first of which is elongate and grooved with a distal trochlear articulation. The second phalange resembles the first of the first toe, but is shorter. The third toe has four phalanges, the proximal one of which is like that of the second toe, but is elongate; the second is broader than long; the third is like the first, but is shorter; the fourth is a short, scarcely curved and obtusely pointed claw. The fourth toe has five phalanges, of which the first, fourth, and fifth resemble the first, third, and fourth of the third toe, the second and third the second of the same toe. This toe is the longest. The fifth has no phalanges. I may add that the foot from which these measurements were taken was found together, with the bones in place or but little displaced, and has been so mounted in the University of Kansas Museum. I have repeatedly examined these bones, and am confident that the number of phalanges are as I have given them; that is, there is an absence of the claws on the first and second toes. The measurements of this specimen are as follows:

	mm.
Femur, length	260
Diameter of head	20
Width of condyles	30
Tibia, length	362
Metatarsals, length	101, 105, 95, 80, 25
Phalange, first digit, length	41
Phalanges, second digit, length	25, 31
Phalanges, third digit, length	35, 4, 27, 12
Phalanges, fourth digit, length	40, 3, 3, 26, 12

Ossified tendons. Numerous thin, flat, striated bones are lying on the matrix associated with the anterior extremity, which can only be regarded as tendinous ossifications. One of these on each side is lying by the side or upon the pteroid bone, with its pointed extremity near its proximal end. They measure one hundred to one hundred and twenty millimeters in length, with a greatest breadth of twelve millimeters. Two others are lying by the side of the proximal end of the right wing metacarpal; they are somewhat shorter and have the flattened fimbriated end distad. Another is lying by the side of the distal end of the same bone. There is a shorter, more fan-shaped one by the right humerus, and fragments of others are scattered about the arms. Altogether there are seven of these of about one hundred millimeters in length. Their texture is striate, as though composed of slender, ossified, tendinous fibers, altogether reminding one very much of similar tendinous ossifications in the legs of many birds.

A number of other slender, rib-like, more or less fragmentary bones are observed scattered about the slab near the body of the specimen, of which I am not at all certain, though I suspect that some of them are ventral ribs, perhaps attached during life to the extremity of the flat parasternal structures already described. One of these bones, lying by the lateral margin of the sacrum is about forty millimeters in length and is gently curved. It is flattened at one end, measuring nearly three millimeters in width, cylindrical at the other, and not more than one millimeter wide. Another, lying back of the pelvis, of about the same length is also slightly curved, one millimeter wide at one end and about three-tenths of a millimeter in width at the other end. There are also parts of several other bones which seem to be similar to these.

SYSTEMATIC POSITION.

Three specimens ascribed to *Nyctosaurus* are now known — the type described briefly by Marsh, the one in the University of Kansas Museum described by me in 1892, and the present one. Marsh must have known more than one specimen, however, in which additional specimens he later recognized the essential generic characters. The three specimens differ materially in size, that described by Marsh being the largest, and the Kansas University specimen the smallest. In the smallest specimen the coracoid and scapula are still distinguished by a separable suture. Furthermore, the separated arches of the dorsal vertebræ, and the distinction of the elements of the atlas all indicate a young animal. On the other hand, the present specimen has all of its sutures obliterated, except that between the atlantal intercentrum and the axial intercentrum, characters which may be ascribed to an adult condition. Among the characters given by Marsh, is the separated coracoid and scapula, but I suspect that this was derived from a smaller specimen than the one which he originally named *Pteranodon gracilis*. I do not think that the absolute differences in size are sufficient to separate the specimens specifically, in that we know that similar differences are ascribed to other pterodactyls by some authors. In order, however, to make the comparative differences between these specimens clearer I have reduced them to a common standard, using the humerus as 100 in each. In addition, I give like comparative measurements of certain species of *Pterodactylus*, derived from figures given by Zittel:

	Nyctosaurus F. C.	Nyctosaurus K. U.	Nyctosaurus type.	Pteranodon ingens.	Pterodactylus Kochii.	Pterodactylus
Humerus	100	100	100	100	100	100
Ulna	165	165	---	136	148	153
Metacarpal	257	275	---	210	106	105
First Phalange	324	327	---	268	161	160
Second Phalange	241	---	---	172	142	129
Femur	93	93	---	106	109	107
Tibia	151	151	---	150	153	144
Metacarpal	100	100	100	---	---	---
Ulna	64	60	62	---	---	---
First Phalange	126	119	115	---	---	---

It is observed that there is a striking agreement in these specimens, except in the metacarpals, the differences elsewhere being scarcely more than one might expect in the measurement of bones differently affected by the compression to which they have been subjected. Now, we may consider this variation of specific value and give to each of these three specimens a different name; or we may, as is far more reasonable, consider the metacarpal as a variable bone in the individual, as it is in the species and groups, and refer them all to one species. This I have no hesitation in doing. There is, then, but a single species of *Nyctosaurus* now known among the specimens referred to the genus; it should be called *Nyctosaurus gracilis* Marsh.

In specimens of *Pteranodon ingens* there is not a little variation in size, especially in the length of the wing metacarpal, which I have observed to vary from 580 to 615 millimeters, the longest that I have ever known from the Kansas chalk. It is very certain, I think, that absolute identity of size cannot be relied upon to distinguish the different species of pterodactyls, nor do I think that the relative or proportional lengths of the finger bones should receive too much weight; the different species evidently varied individually within certain limits.

In my first paper on *Nyctosaurus*, I discussed briefly the so-called species of *Pteranodon*, *P. nanus*, and *P. comptus*, suspecting that one or both of them belonged with *Nyctosaurus*.

A wider acquaintance with Kansas pterodactyls, both in the laboratory and in the field strengthens my belief that both of these names are synonyms of *N. gracilis*.

No small species from the Kansas chalk can be referred definitely to *Pteranodon*, so far as my own knowledge goes, and I have seen hundreds of specimens. *P. nanus* presents the strong lateral crest of the humerus which I am satisfied is a diagnostic characteristic of *Pteranodon*. Although the author expressly stated that the "coracoid and scapula were firmly anchylosed" a character seen in the present specimen of *Nyctosaurus*, I feel pretty confident that the type of *P. nanus* does not have the articular extremity of the scapula so characteristic of *Nyctosaurus*. The description of *P. comptus* might apply, except in size, to either *Nyctosaurus* or *Pteranodon*. I refer the species to the former genus because of its small size, but its synonymy is not assured. That a better basis for an opinion may be given the reader, I here reproduce all that Marsh has written upon *Nyctosaurus* and the two small species which he referred to *Pteranodon*.

"One of the smallest American species yet found is represented in the Yale Museum by several bones of the wing, a number of vertebræ and the nearly complete pelvis. The wing bones preserved are elongated and very slender. The pelvis is unusually small, and there are five vertebræ in the sacrum. The last of the series indicates that the tail was short. The following are the principal dimensions of this specimen:

	mm.
Length of ulna	187
Length of metacarpal of wing finger	300
Antero-posterior diameter of outer condyle at distal end	15
Tranverse diameter of shaft, above condyles	13
Length of first phalanx of wing finger	347
Extent of five vertebræ of sacrum	57

"This species, which may be called *Pteranodon gracilis*, was about two-thirds the size of *P. velox* Marsh. It probably measured about ten feet between the tips of the expanded wings."*

"*Pteranodon comptus*, sp. nov. The smallest Pterodactyle known from American strata is indicated by portions of three skeletons in the Yale Museum. Among these remains are two distal ends of the characteristic metacarpal of the wing finger, other portions of the wing bones, and two sacral vertebræ. The large metacarpal is very slender and elongated, and its outer distal condyle has its superior margin elevated above the shaft, and terminated proximally in a point. The ulna is comparatively large, and the proximal carpal has an oval air cavity on its radial side. The sacral vertebræ have their centra short, and medially constricted.

"The principal measurements of the remains of this species are as follows:

	mm.
Greatest diameter of ulna at distal end	15
Transverse diameter of proximal carpal	17
Antero-posterior diameter of outer distal condyle of wing metacarpal	12.8
Longitudinal extent of condyle	11.6
Transverse diameter of shaft above condyle	11.5
Length of medial sacral vertebra	9
Transverse diameter of centrum	8.4

---

*Marsh, Amer. Journ. Sci. June, 1876, p. 508.

"The above specimens are all from the Upper Cretaceous of Western Kansas."*

"*Nyctosaurus*, gen., nov." A second genus of American Pterodactyls is represented in the Yale Museum by several well-preserved specimens. This genus is nearly related to *Pteranodon*, but may be readily distinguished from it by the scapular arch, in which the coracoid is not co ossified with the scapula. The latter bone, moreover, has no articulation at the distal end, which is comparatively thin and expanded. The type of this genus is *Pteranodon gracilis* Marsh, which may now be called *Nyctosaurus gracilis*. It was a Pterodactyl of medium size, measuring about eight to ten feet between the tips of the expanded wings. Its locality is in the Upper Cretaceous of Western Kansas. The type specimens of all the above species are preserved in the Museum of Yale College."†

"In the same geological horizon with the gigantic forms (Pteranodon beds) the remains of a single small Pterodactyl have been found. This animal was more diminutive than the Jurassic species [*Dermodactylus montanus*], having a spread of wings not more than three or four feet. The jaws were proportionally more slender than in the larger Cretaceous species, and no teeth have been found with them. The humerus had a small head and an enormous radial crest, which curved downwards. The scapula and coracoid were firmly ankylosed. Some of the trunk vertebræ have very long transverse processes, or ankylosed ribs, curved backward. Some dimensions of this specimen are as follows:

Length of humerus	62
Greatest diameter of head	12
Transverse diameter across radial crest	30
Greatest diameter of distal end	16
Vertical diameter of humeral glenoid cavity	13
Transverse diameter	6

"This species may be called *Pteranodon nanus*. Its known remains were found by Mr. S. W. Williston, in the Middle Cretaceous of Western Kansas."‡

"The name *Nyctosaurus*, applied by the writer to this group, appears to have been preoccupied, and hence may be replaced by *Nyctodactylus*. The only species known is *Nyctodactylus gracilis*."‖

It is seen that but five vertebræ are referred to the sacrum of the type of *Nyctosaurus gracilis*; if this be a real character one would not question the distinctness of the species. Inasmuch as *Pteranodon* has six vertebræ in the sacrum and one or more lumbars or false sacrals, as in the present specimen of *Nyctosaurus*, I believe that this number will be found common to all the Kansas pterodactyls. I think that Marsh must have been in error in ascribing but five to the sacrum. Should he, however, be correct I would suggest the name *N. leptodactylus* for the present species.

---

*Marsh, l. c., p. 509.

† Marsh, Amer. Journ. Sci. Dec., 1876, p. 480.

‡ Marsh, Amer. Journ. Sci. April, 1881, p. 343.

Marsh, Amer. Journ. Sci. April, 1881, p. 343, footnote.

In view of the foregoing I offer the following as the synonymy of this genus and species:

NYCTOSAURUS.

Marsh, Amer. Journ. Sci., xii, p. 480, Dec., 1876. *Nyctodactylus* Marsh, Amer. Journ. Sci., xxii, p. 343, April, 1881 ; ibid., xxvii, p. 423, May, 1884. Williston, Kans. Univ. Quart., i, p. 2, 5, 1893; Journ. Anatomy, i, p. 297, 1902 ; Journ. Geology, x, p. 520, July–Aug. 1902.

NYCTOSAURUS GRACILIS.

Pteranodon gracilis Marsh, Amer. Journ. Sci., xi, p. 508, June, 1876.

Nyctosaurus gracilis Marsh, Amer. Journ. Sci. xii, p. 480, Dec. 1876.

Nyctodactylus gracilis Marsh, Amer. Journ. Sci. xxi, p. 343, April, 1881; Williston, Kans. Univ. Quart., i, p. ii, 1893; Zittel's Paleontology (Eastman), vol. ii, p. 255, Fig. 361, 1902.

(?) *Pteranodon comptus* Marsh, Amer. Journ. Sci. xi, 508, June, 1876; Williston, Kans. Univ. Quart. i, p. 11, June, 1893.

(?) *Pteranodon nanus* Marsh, Amer. Journ. Sci., April, 1881, p. 343; Williston, Kans. Univ. Quart. i, p. 11, June, 1893.

Of the remaining species of Kansas pterodactyls, six have been described, two of which, *P. umbrosus* and *P. harpyia* Cope, are admittedly identical with previously described forms, leaving *ingens*, *occidentalis*, *velox*, and *longiceps* Marsh. No real attempt was made to separate *P. longiceps* from those previously named, nor could there have been, since only the skull was known in this species to the describer, while the skull was not known in either of the other species. It may be identical with either *occidentalis* or *velox*, possibly with both. The characters given by Marsh to distinguish the species have little value, though I believe there are three distinct ones of the genus, known from the Kansas chalk. Two of these species are at once distinguishable by the structure of the humerus, especially of its radial or lateral crest. In *P. ingens* this crest is rounded and obtuse; in one or the other of the smaller forms it is more elongate and of a different shape. Furthermore, among the smaller specimens there appear to be two different types of terminal wing phalange, one nearly straight and the other curved falciform, as in *P. ingens*. If the smaller form with the curved phalange should prove not to be the young of *P. ingens*, as is not likely, then we have at least three distinctly different species of the genus, perhaps a fourth in *P. comptus*.

A much more interesting question is: What relation do the genera, *Nyctosaurus*, *Ornithocheirus*, and *Pteranodon* (*Ornithostoma*) bear to each other and to *Pterodactylus*?

The classification which has hitherto seemed the best to display the relationship of these forms is the following:

Suborder Pterodactyloidea. Tail short; wing metacarpal, at least as long as the bones of the antebrachium; fifth digit of pes vestigial, without phalanges.

Family Pterodactylidae. Scapula not articulating with supraneural facet.

Genus *Pterodactylus*. Teeth present.

Genus *Nyctosaurus*. No teeth.

Family Ornithocheiridæ. Scapula with an articular facet united with neural facet of the notarium.

Genus *Ornithocheirus*. Jaws with teeth.

Genus *Pteranodon* (*Ornithostoma*). Jaws without teeth.

However, a better knowledge of the genus *Nyctosaurus* convinces me that its relationship is closer with *Ornithocheirus* than with *Pterodactylus*; that it has gone much further in specialization in the same direction with ***Ornithocheirus*** and ***Pteranodon***. Very little now remains to be known of the osteology of both these genera, and not much of ***Ornithocheirus***. Their characters as a group may be summed up as follows. While some parts of the skeleton of ***Ornithocheirus*** are yet unknown, I am confident that future discovery will produce nothing very discrepant.

Ornithocheiridæ. Head elongate, slender; no antorbital vacuity; internal nares large; eight cervical, ten dorsal (***Pteranodon?***), six sacral, and ten to twelve caudal vertebræ present, the last dorsal co-ossified with the sacrum; first three or four dorsal vertebræ united into a notarium, with stout, anchylosed ribs articulating with the sternum; posterior dorsal ribs very slender, single-headed, and nearly straight; three or four pairs of flattened V-shaped ventral ribs present. Ilium much elongated; ischio-pubis with an obturator foramen; prepubes band-like, co-ossified, with an anterior, flattened projection on each side. Coraco-scapula with only a slight projection below the glenoid cavity, co-ossified in the adult; scapula but little longer than the coracoid, not narrowed distally. Three carpals present; forearm much longer than humerus; third and fourth metacarpals very short, pointed proximally, not articulating with carpus; second metacarpal thread-like proximally; fifth metacarpal much longer than forearm; phalanges proportionally long. No fibula present; two tarsals only; fifth digit without phalanges.

Ornithocheirinæ. Upper end of scapula thickened, articulating with a supraneural plate. Head with a prominent parieto-occipital crest.

Ornithocheirus. Jaws with teeth.

Pteranodon (*Ornithostoma*). Jaws wholly edentulous.

Nyctosaurinæ. Scapula flattened spatulate above, not articulating with supraneural plate. Humeral crest constricted; humerus proportionally short, the digit long; no sagittal crest.

Nyctosaurus, *Ornithodesmus* (?).

In contradistinction to these characters I would define the *Pterodactylidæ* as follows: I have never seen any specimen of this genus, and must, therefore, rely entirely upon the descriptions and figures. The characters hence are in a measure provisional.

Pterodactylidæ. A distinct antorbital foramen present, sometimes partly confluent with the nares; occiput not produced, jaws always with teeth. No consolidation of the thoracic vertebræ or anchylosis of the sternal ribs, the posterior ribs less slender. More than ten vertebræ in the dorsal region and less than six in the sacrum. Prepubes never co-ossified in the middle, and without anterior prolongation. Scapula longer than the coracoid, more or less narrowed distally. Humerus and legs relatively large, the forearm and wing finger relatively small; all the metacarpals articulating with the carpus. A fibula present.

I am sure that all these characters are generalized ones, even as the genus is older than those placed in the first group. It seems to me especially that the shortening of the back, the consolidation of the early dorsal vertebræ, and the elongation of the sacrum, with the greater elongation of the wing digit, are better evidences of relationships than is the presence of the peculiar scapular articulation.

Certain conclusions as to the habits of the *Ornithocheiridæ*, as I here define the family, seem inevitable from a better knowledge of their structure. Some of these conclusions I have already presented in a former paper, and a further study only strengthens my belief in their justness.

The neck was strong, with limited torsion, but with great power and effectiveness in the antero-posterior flexion, thus rendering the beak very effective in striking.[*] The marked posterior projection of the hind zygaphophyses of the last cervical vertebra, quite unlike those of any other vertebræ in the column, indicates, not that the neck turned backward at this place, but that it curved forward more after the way of birds, a position compatible with the upright attitude. The whole structure of the neck, the elongated vertebræ, the transverse centra, and lateral exapophysial articulations, the absence of transverse processes, all remind one of the neck in the cryptodire testudinates, where the neck is capable of much and effective antero-posterior flexion.

---

[*] Plieninger (op. cit.) misquotes me in saying that "Williston glaubt, dass diese Art der Articulation die Bewegung des Halses in verticaler Richtung von vorne nach hinten eingeschrankt hat." What I said was: "Such a mode of articulation would seem to limit the motion to one in a vertical, antero-posterior plane, while greatly strengthening the joints."—Kans. Univ. Quart., vi, p. 39.

The articulation of the head of the femur, with the basal plane of its convexity nearly at right angles to the long axis of the bone, and the posterior position of the acetabulum, carry conviction to me that the femora could not have been brought parallel in the same direction without dislocation from the sockets, whatever attitude the animal may have assumed. The articulation of the distal end of the tibia furthermore shows that the metatarsus could not have been extended to a right angle; that is, *Pteranodon* could not have been plantigrade. The greater extension must have been between the metatarsus and phalanges; in other words, the creature must have been digitigrade in ambulation. The flattened proximal ends of the metatarsals indicate a compact and closely united foot, and the bones have been so found in specimens of *Pteranodon*. The toes in *Pteranodon*, and doubtless in this genus also, were practically clawless, and the outer toes were much the longer. The animal was incapable of seizing or holding with the feet.

Nor could a very great flexion at the knee have been possible, as I think the figures of the femur of *Pteranodon ingens* will indicate. If the animal was quadrupedal, it must have been in a crawling attitude, with both legs and arms widely extended.

APATOMERUS MIRUS, GEN. ET. SP. NOV.

In the University of Kansas Quarterly, vol. iii, p. 3, I described and figured a remarkable bone from the Lower Cretaceous of Clark County, Kansas, which I hesitatingly referred to some crocodile-like animal, because I was at a total loss where else to place it, my knowledge of the pterodactyl anatomy then being less than at present. The figure and description are reproduced in vol. iv of the University Geological Survey of Kansas, p. 90, as follows: "The upper end of a femur found in the same region appears to belong to the same kind of an animal, as does the vertebra described above. The shape is not unlike that of a human femur, with the trochanters evidently small and placed much below the level of the head. The neck is stout, the head gently convex, with an angular border. The shaft below the trochanters is somewhat flattened from before backward, but becomes more cylindrical below. The shaft is hollow, with firm walls not more than one-third of an inch in thickness. The portion preserved measures 210 mm."

I am now satisfied that the femur in question belongs to a heavy-boned pterodactyl or some allied, hitherto unknown, animal. The very peculiar head of the bone with its articular convexity directed upward, the position of the trochanter, the hollow shaft and its curvature are characters all found in pterodactyls and in no other animals of which I have any knowledge. The entire length of the bone must have been about 350 or 400 mm., and while the walls are unusually thick, they are not proportionally much more so than in *Dermodactylus*, the type of which I distinctly remember. *Dermodactylus* is from the so-called fresh-water beds of the Wyoming Jurassic, which I have long believed to be contemporaneous with the Comanche beds of Kansas, and which I correlate with the Wealden of Europe. The forms cannot be the same, since this is very much larger.

MAY 14, 1903.

In an article by Mr. F. A. Lucas in the Report of the Smithsonian Institution for 1901, there is given an excellent drawing of a skull of *Pteranodon* (*Ornithostoma*), made "from a specimen in the Yale University Museum." From my recollection of various peculiarities shown in the figure, as also from certain accidental peculiarities, such as the fracture of the infra-narial bar, faithfully reproduced in Professor Marsh's drawings, I have very little hesitation in saying that the specimen there illustrated is the type of the genus *Pteranodon*, upon which was based the figure so long current in text-books. Should I be in error in this identification, I shall be glad to be corrected, hoping, however, in that case, that a true figure of the type specimen may be published.

In the summer of 1891, Professor E. C. Case and myself uncovered from the firm yellow chalk of western Kansas, the uninjured posterior part of a skull of *Pteranodon*, with its sagittal-crest entire and evenly rounded. A figure of this specimen was given in Pl. I, Vol. I, of the Kansas University Quarterly, to which I beg to refer the reader. The specimen is now preserved on a slab in the museum of the University of Kansas, and I doubt not that the crest as disclosed from the matrix and as represented in the figure, is all that the animal possessed in life. Mr. G. F. Eaton, however, in the July number of the American Journal of Science takes me to task for criticising the original figures of *Pteranodon*, which he admits were faulty, and for my "restoration" of the skull, asserting that I was wrong. He now adds to the type a much longer crest than did the author. The basis for Professor Marsh's restoration is shown in Mr. Lucas's plate, if my identification is correct, and the drawing has been faithfully made.

I do not criticise Professor Marsh for making the restoration as he did; he was perhaps justified, though it might have been better had he stated how much of the restoration was conjectural, and had also published a figure of the specimen as it actually was.

In his present paper Mr. Eaton says: "At the present time of writing an incomplete Pterodactyl skull is being worked out at the Yale Museum, which will, in all probability prove to be that of *Nyctodactylus* Marsh. The crest, which is apparently entire, is of small size compared with that of *Pteranodon*, the measurement from occipital condyle to tip of crest being only 49 mm., while the length from occipital condyle to tip of beak was approximately 45 cm. In general the skull compares favorably with that shown in Williston's restoration of *Nyctodactylus*, given in the American Journal of Anatomy, Vol. I, No. 3, May 26, 1902, where he states that the outline is taken in part from a specimen of *Pteranodon* Marsh, or *Ornithostoma* Seeley, as the genus was then called. It is therefore fair to infer that the apparent similarity of the two genera led Williston to draw inadvertently upon the characters of *Nyctodactylus* in making his restoration of *Pteranodon*."

Had Mr. Eaton done me the honor to have read more attentively the article which he quotes; or had he examined the extended article on the skull of *Nyctodactylus* with plates, published in the Journal of Geology for August, 1902; or even had he examined the figure of the skull in Zittel's text-book of Paleontology, published last autumn, of all of which he seems strangely ignorant, he would have learned that *Nyctodactylus has no crest whatever*, not even a vestige of one! It is very evident, therefore, that Mr. Eaton has made the very error which he so freely suggests I have made, and that his specimen is in reality a *Pteranodon!* I am pleased to learn that its "apparently entire" "crest" compares favorably with that which I have assigned to the same genus.

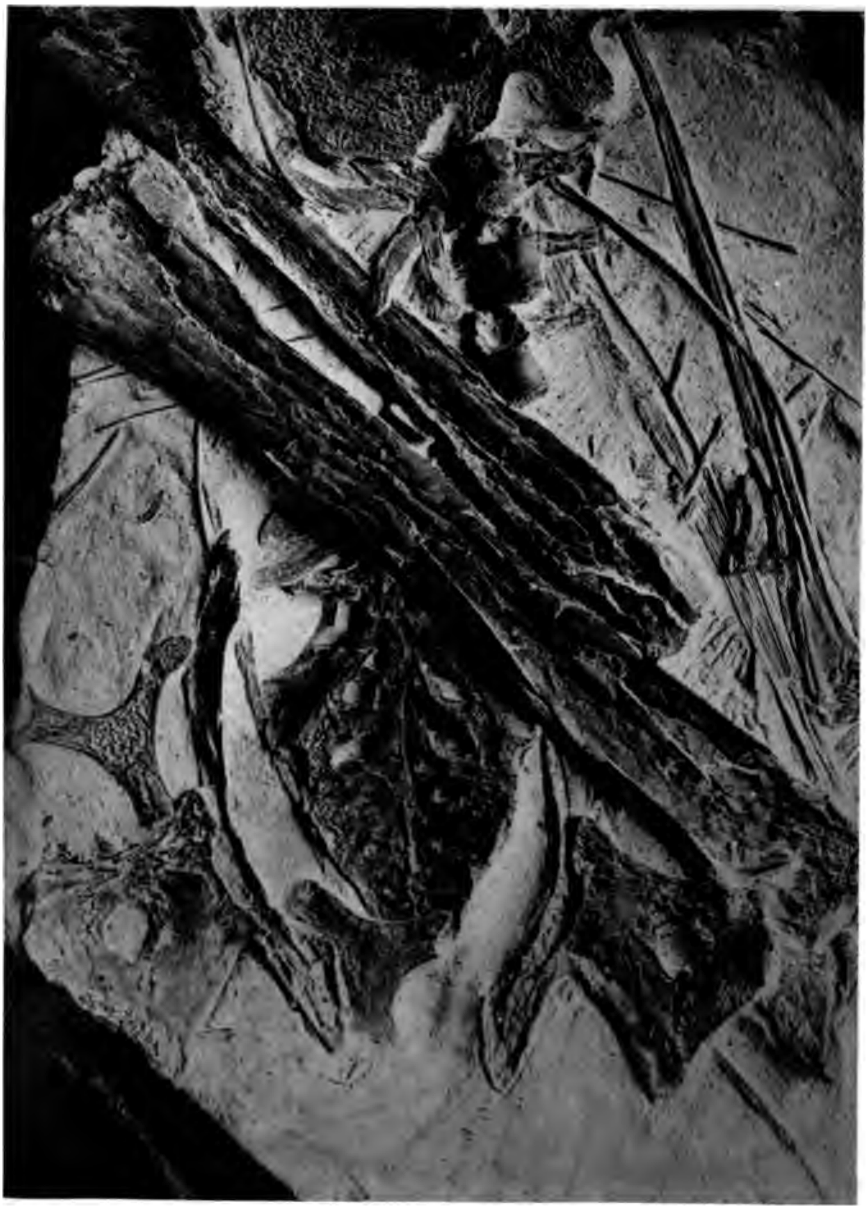
Now, since his own observations show that *Pteranodon* may have a short crest, very much as I have figured it, it will be of interest to learn more fully his reasons for attaching the elongated crest he has to the skull as shown in Mr. Lucas's figure. I furthermore note that Mr. Eaton continues, in his "restoration" of the skull of *Pteranodon*, the gravest of the inaccuracies of the original figures, the absence of the supratemporal fossa and arch. If he is correct in this, the original reference of the genus to a distinct order of reptiles was justified. But we will await further evidence before assuming that he is, and meanwhile, it will be unfortunate if his restoration finds currency.

Inasmuch as Mr. Eaton has so clearly shown his ignorance of recent and very accessible literature on the subject, it is too much to expect that he would have mentioned the fact that the pelvis of *Pteranodon* has been

PLATE XL.

NYCTOSAURUS GRACILIS.

View of part of specimen, showing sternum, pelvis, dorsal vertebræ, ribs and arm bones. Natural size.



Nyctosaurus gracilis Marsh.

PLATE XLI.

NYCTOSAURUS GRACILIS.

Fig. 1. Dorsal vertebræ, ribs, and pelvis; about three-fifths natural size. *r*, ribs; *dv*, lumbar or false sacral; *s*, sacrum; *ip*, ischio-pubis; *ob*, obturator foramen; *il*, ilium; *pp*, prepubes.

Fig. 2. Abdominal ribs. About three-fifths natural size.

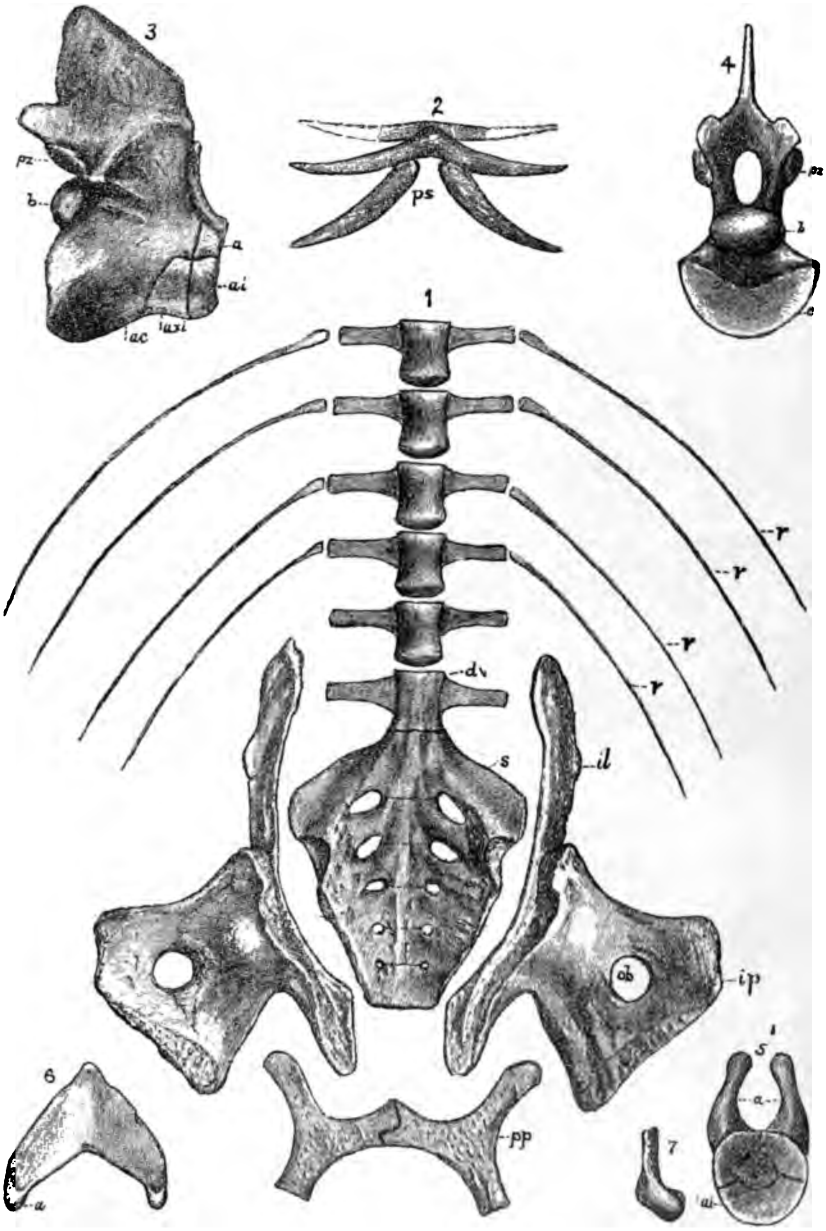
Fig. 3. Atlanto-axis, from the side. Twice natural size.

Fig. 4. The same from behind, partly restored.

Fig. 5. The same, from in front: *a*, atlantal neurapophysis; *ac*, axial centrum; *ai*, atlantal intercentrum; *axi*, axial intercentrum; *b*, ball of axis; *o*, odontoid; *pz*, postzygapophysis.

Fig. 6. Hyoid bone. Three times natural size.

Fig. 7. Extremity *a* of Fig. 6, more enlarged, from the side.



S. W. W. del.

Nyctosaurus.

PLATE XLII.

NYCTOSAURUS GRACILIS.

Fig. 1. Sternum, from below. Three-fifths natural size.

Fig. 2. Left radius, ulna, and carpus, from inner side, the carpus somewhat displaced: *a*, radius; *b*, ulna; *c*, proximal carpal; *d*, distal carpal.

Fig. 3. Right lateral carpal or first metacarpal.

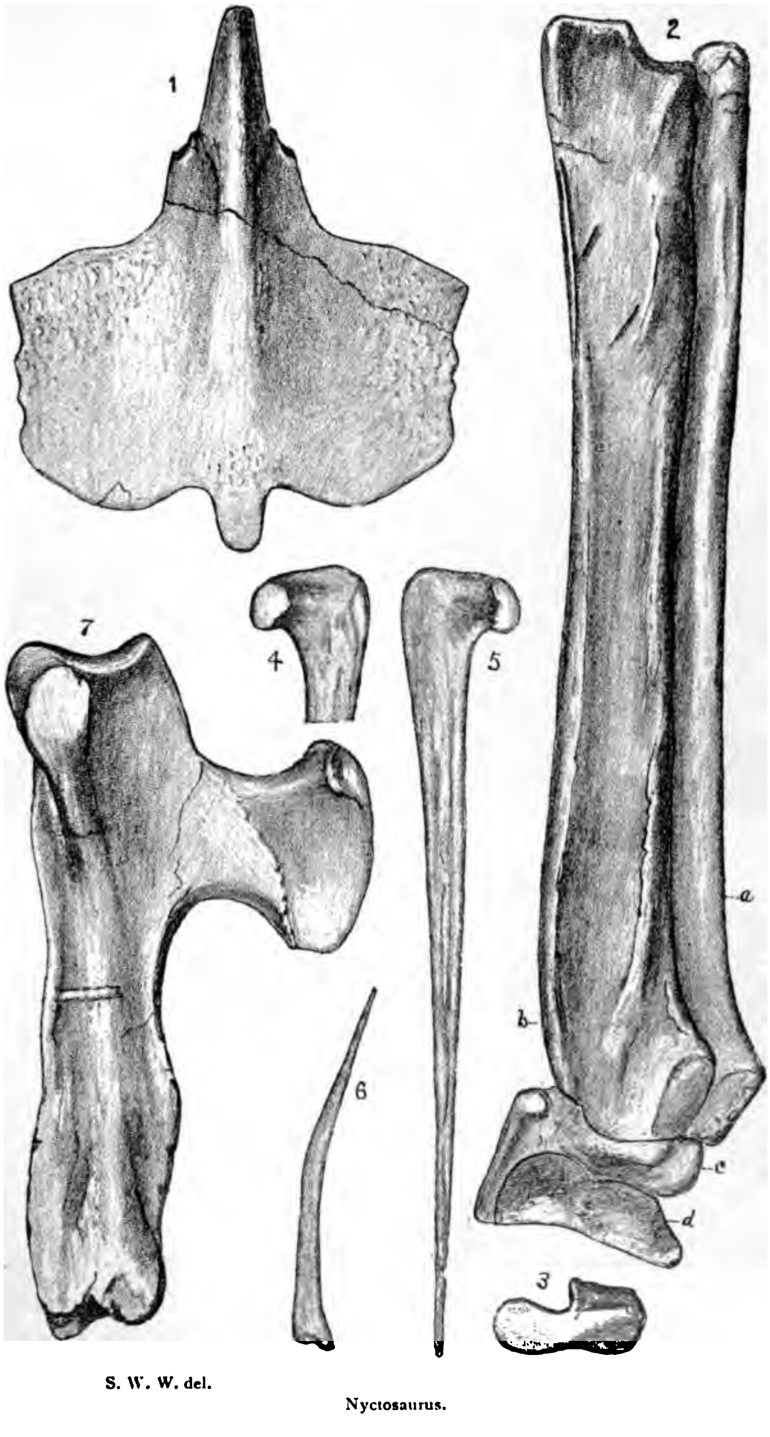
Fig. 4. Right pteroid bone, from in front.

Fig. 5. Right pteroid, from behind.

Fig. 6. Small metacarpal. Twice natural size.

Fig. 7. Left humerus, from within.

All the figures, except as stated, natural size.



S. W. W. del.

Nyctosaurus.

PLATE XLIII.

Fig. 1. Left femur of *Pteranodon ingens*, somewhat obliquely compressed, from in front showing dermal markings. One-half natural size.

Fig. 2. The same, posterior surface. One-half natural size.

Fig. 3. The same, distal end. One-half natural size.

Fig. 4. Right femur of *Nyctosaurus gracilis*, from in front. Natural size.

Fig. 5. The same, from behind. Natural size.

Fig. 6. Left coraco-scapula of *Nyctosaurus gracilis; s*, scapula; *c*, coracoid; *a*, process of scapula. Natural size.

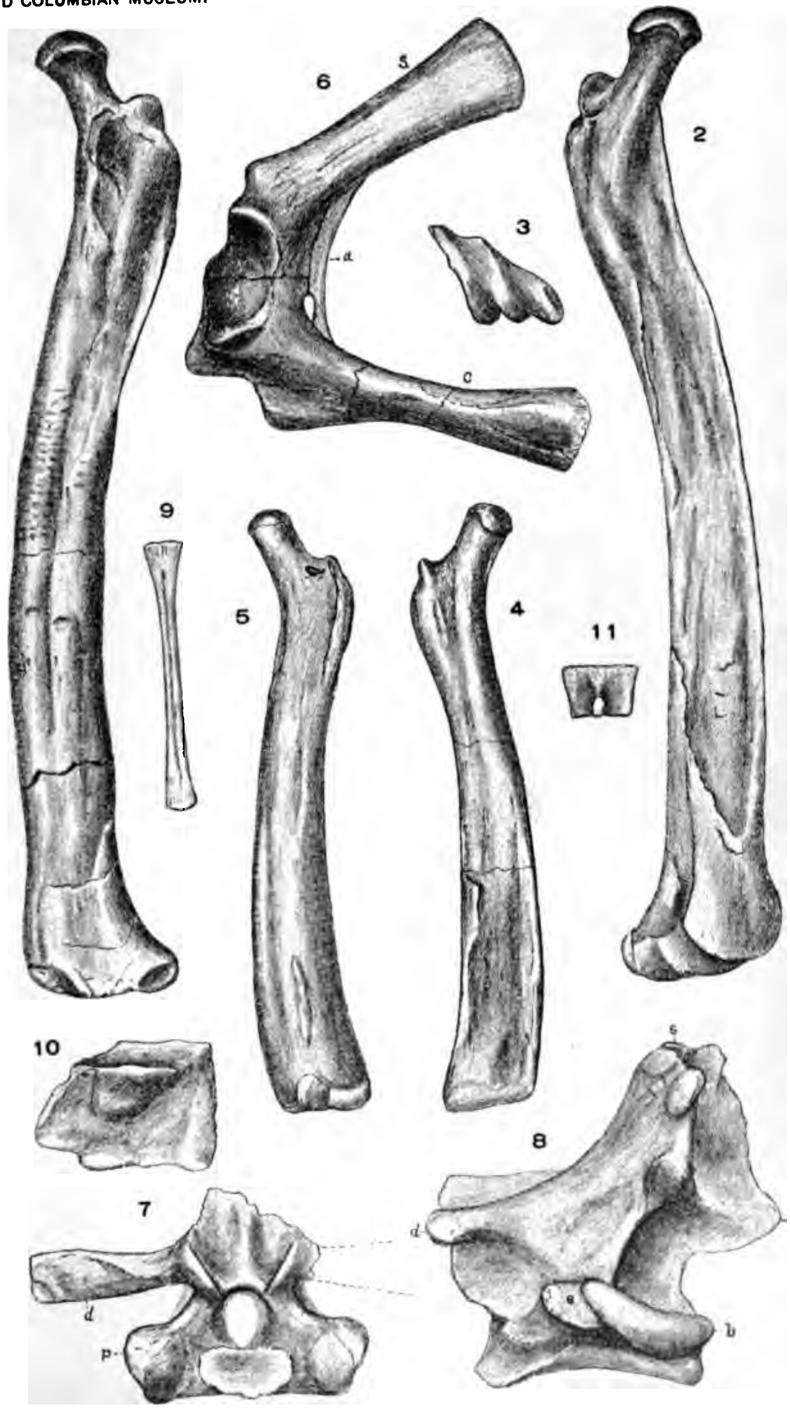
Fig. 7. First dorsal vertebra of *Nyctosaurus gracilis*, from in front. Twice natural size.

Fig. 8. Eighth cervical vertebra of *Nyctosaurus gracilis*, as compressed, obliquely from behind: *s*, spine; *b*, ball; *d*, diapophysis; *e*, exapophysis. Twice natural size.

Fig. 9. Metatarsal of *Nyctosaurus gracilis*. Natural size.

Fig. 10. Right distal carpal of *Nyctosaurus gracilis*, obliquely from behind. Natural size.

Fig. 11. Proximal caudal or caudo-sacral vertebra of *Nyctosaurus gracilis*, from above. Natural size.



S. W. W. del.

Pteranodon, Nyctosaurus.

PLATE XLIV.

Fig. 1. Right first wing phalange of *Nyctosaurus gracilis*. One-half natural size.

Fig. 2. Right wing metacarpal of *Nyctosaurus gracilis*, from below. One-half natural size.

Fig. 3. Tibia of *Nyctosaurus gracilis*, from the side. Natural size.

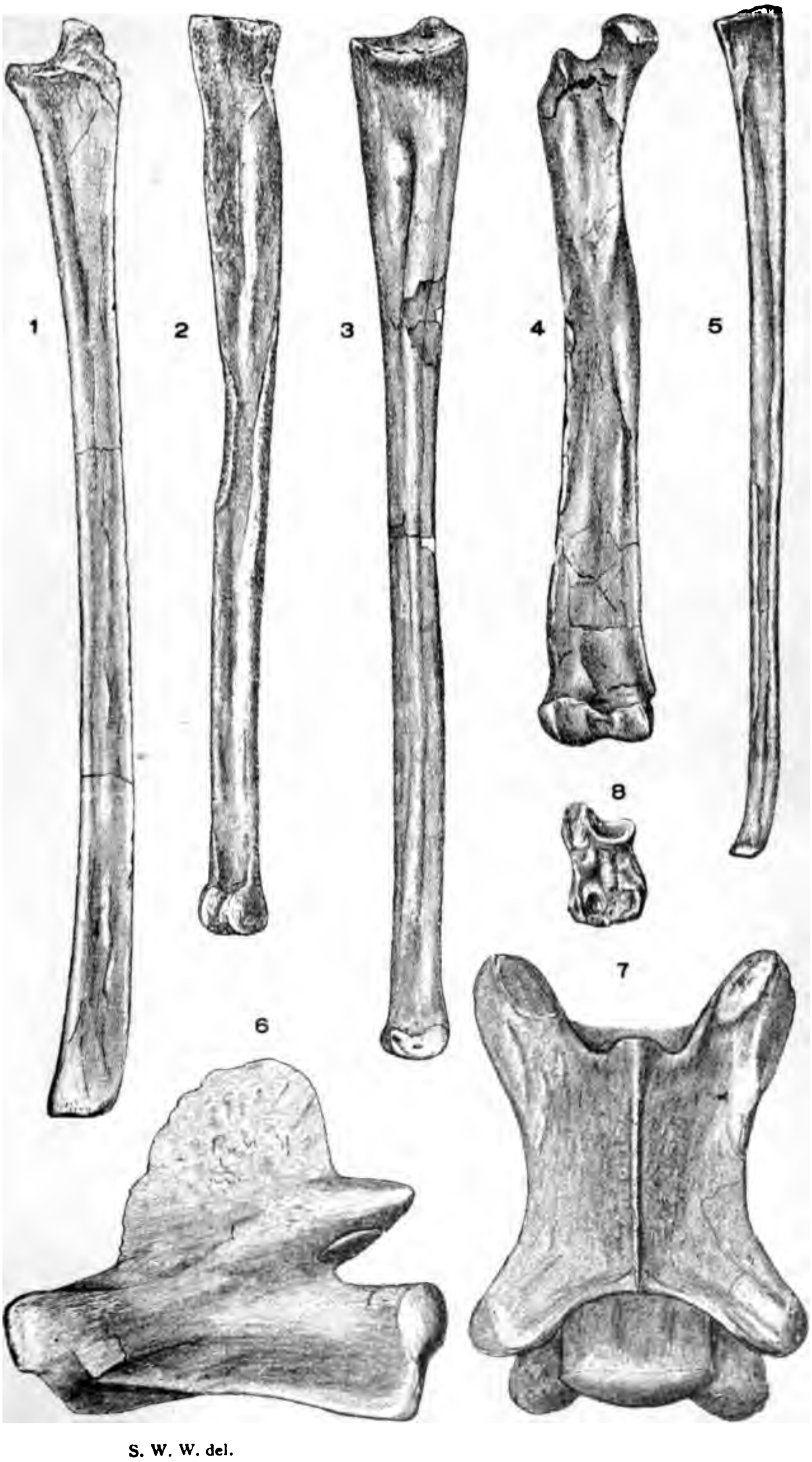
Fig. 4. Left femur of *Pteranodon occidentalis*(?) Marsh, from behind. One-half natural size.

Fig. 5. Right second wing phalange of *Nyctosaurus gracilis*, from behind. One-half natural size.

Fig. 6. Posterior cervical vertebra of *Nyctosaurus gracilis*, from the side. Twice natural size.

Fig. 7. Fifth cervical vertebra of *Nyctosaurus gracilis*, from above. Twice natural size.

Fig. 8. Lateral carpal of *Pteranodon ingens*, after Cope. One-half natural size.



S. W. W. del.

Pteranodon, Nyctosaurus.

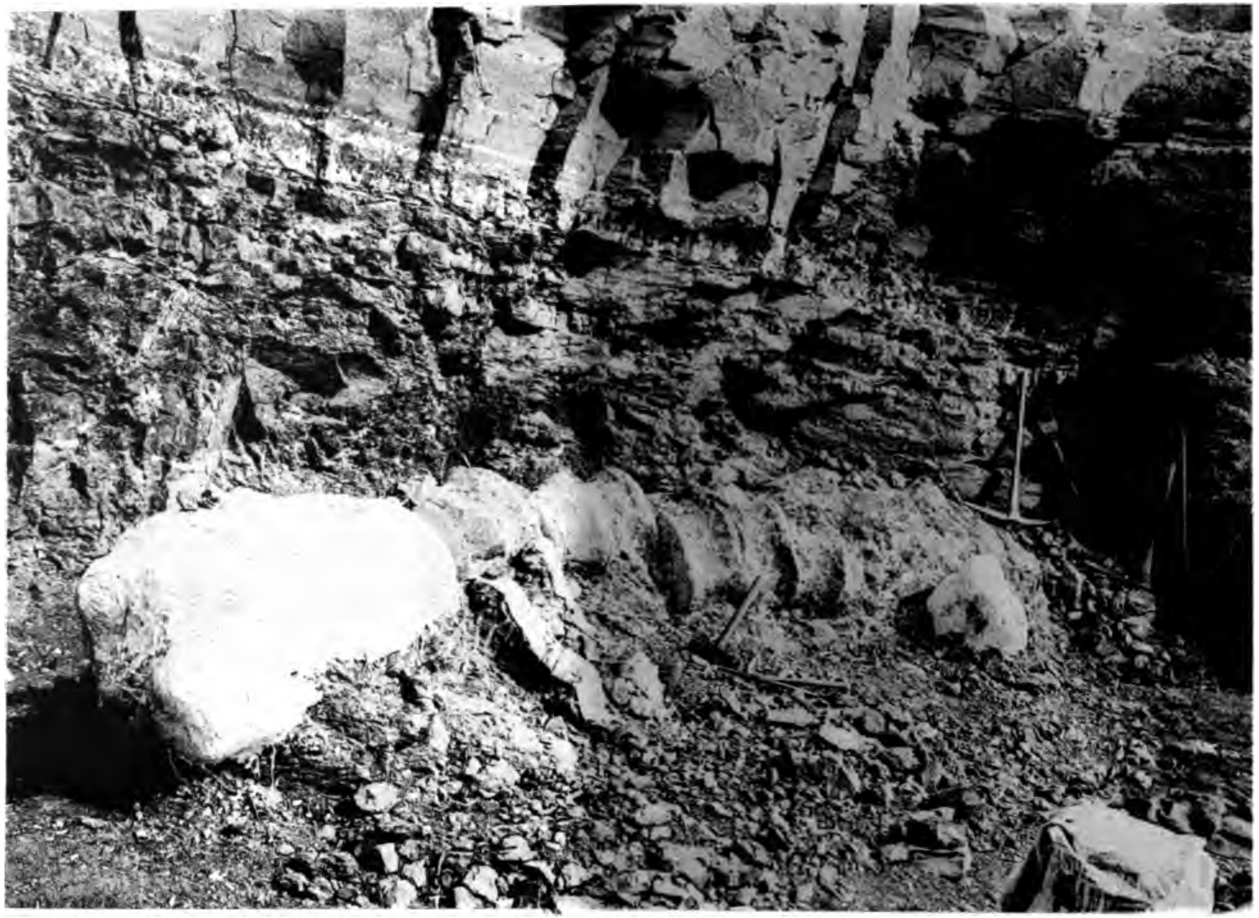


PLATE XLV.

APATOSAURUS.

FIELD COLUMBIAN MUSEUM

PUBLICATION 82.

GEOLOGICAL SERIES. VOL. II, NO. 4.

STRUCTURE AND RELATIONSHIPS OF OPISTHOCŒLIAN DINOSAURS.

PART I.

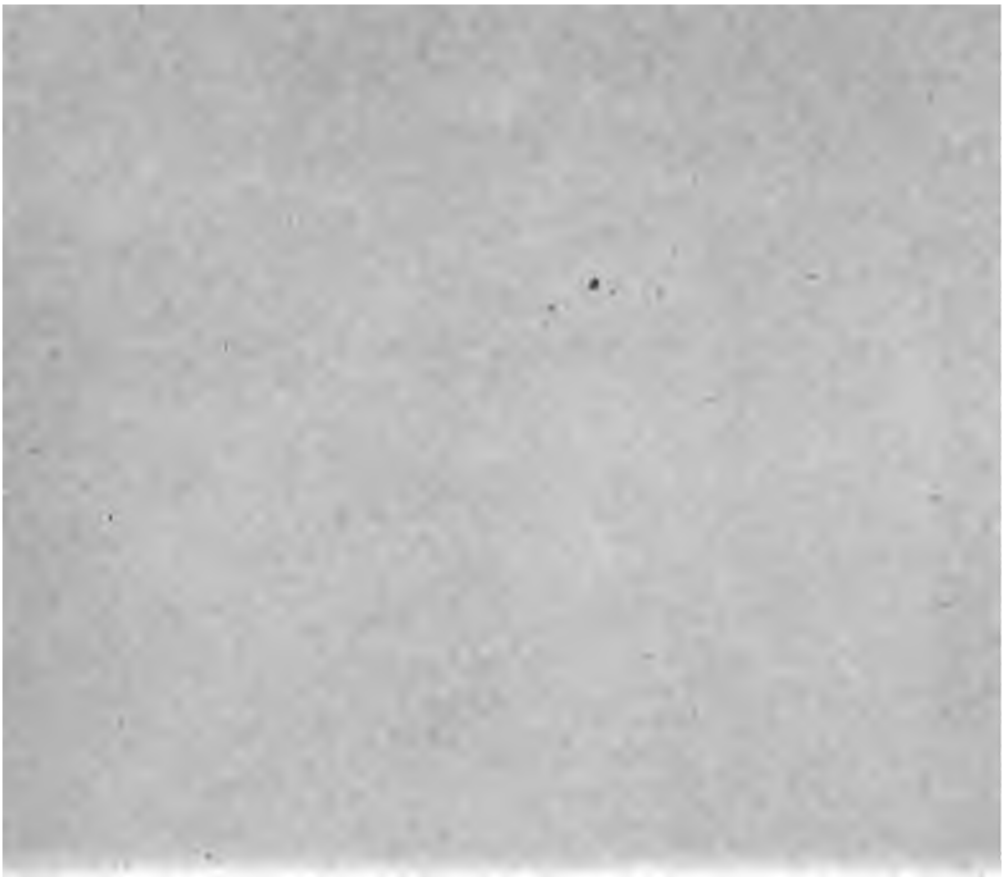
APATOSAURUS MARSH

BY

ELMER S. RIGGS, A.M.
Assistant Curator, Division of Paleontology.

OLIVER CUMMINGS FARRINGTON, PH. D.
Curator of Geology.

CHICAGO, U. S. A.
August 1, 1903



STRUCTURE AND RELATIONSHIPS OF OPISTHOCŒLIAN DINOSAURS.

PART I.

APATOSAURUS[*] MARSH.

BY E. S. RIGGS.

The genus *Brontosaurus* Marsh was described[†] in 1879 from a well preserved skeleton found near Lake Como, Wyoming. The completeness of this specimen and the widely published restorations based upon it have caused this genus to be long regarded as the best known of all the American Opisthocœlia.[‡] However, many questions of morphology were left in doubt by this famous specimen. No skull which could be identified with the genus has ever been described; that figured in Marsh's restoration is based upon a comparison with the skull of *Morosaurus*. The structure of the hind feet was not made clear until figured by Osborn in 1899,[§] while the structure of the fore foot remained a matter of conjecture until figured by Hatcher in 1902.[‖] The vertebral formula of the dorsal and caudal series, as well as many sacral and pelvic characters, has remained to be determined by an unusually well preserved skeleton just placed upon exhibition in the Field Columbian Museum.

The specimen under consideration (Mus. No. 7163) was collected by the Museum Paleontological Expedition of 1901, in charge of the writer, ably assisted by Mr. H. W. Menke. It was found in the Grand River Valley near Fruita, Colorado, in a geological horizon[¶] probably equivalent to the Como Beds of Wyoming. The specimen was discovered in the fall of 1900, but owing to the lateness of the season, its removal was deferred until the following spring.

When found the last cervical vertebra was projecting from a steep hillside. The thoracic series led diagonally into the face of the hill, leaving the distal ends of a number of ribs exposed and partially broken away. Ten feet farther along the bank the distal end of the femur appeared. So hard was the concretionary matrix, in which the skeleton was encased, that drills and dynamite were at once called into service in order to make the excavation necessary for its removal. When the pelvis was reached the face of the stripping was eighteen feet in height. From this point the series of caudal vertebræ curved backward, and dipping rapidly with the strata, led almost directly into the hillside. These conditions made it necessary to resort to tunneling. Accordingly a chamber twenty feet in length by eight feet in breadth was excavated before the search for displaced caudal vertebræ was abandoned.

---

[*] *Brontosaurus*, Marsh, is shown to be a synonym of *Apatosaurus*.

[†] Am. Jour. Sc. Vol. xviii, p. 503.

[‡] Sauropoda and Cetiosauria are shown to be synonyms of Opisthocœlia.

[§] Bull. Am. Mus. of Nat. Hist., Vol. xii, pp. 161–172.

[‖] Annals of the Carnegie Museum, Vol. i, pp. 356–76.

[¶] See "The Dinosaur Beds of the Grand River Valley of Colorado," this publication, Geol. Series, No. 9.

The specimen as a whole was lying upon its right side, and apparently the entire skeleton had been present when embedded. The cervical vertebræ and the fore legs had been carried away by a process of erosion so slow that comparatively few fragments were found upon the surface. The vertebræ from the last cervical to the thirteenth caudal were but slightly displaced from their normal positions. (See frontispiece.) The remaining ten caudal vertebræ recovered were found more and more dissociated, until tunneling for them became unprofitable. Some of the chevrons were associated with the vertebræ, but most of them were displaced. The ribs were found in close apposition with their respective vertebræ. The right ilium was in position and coössified with the sacrum; the femur was scarcely removed from the acetabulum. The pubes and ischia were slightly displaced; the left ilium was fragmentary.

This specimen has been prepared for exhibition with great care and patience, employing the energies of three skilled men for more than eighteen months. The spines and transverse processes of many vertebræ were more or less distorted by the compressure to which they had been subjected in the matrix. So far as was practicable, these distortions have been readjusted. The inevitable missing fragments have been replaced by plaster and carefully colored to match the adjacent parts. All portions thus restored are marked out by a line, not so conspicuous as to mar the general appearance of the specimen, but distinct enough to be readily recognized when examined closely.

For information concerning the type specimen of *Brontosaurus*, and for advice in the preparation of this paper, the writer is indebted to Dr. S. W. Williston of the Museum staff.

SYNONYMY.

The number of terms applied to the group of reptiles variously designated as Sauropoda, Cetiosauria, and Opisthocœlia has led to confusion, at once annoying to the investigator and puzzling to the student. The oldest member of the group and the best known of the European genera is *Cardiodon.*[*] This was described by Owen in 1841, and for a long time included under the Crocodilia.

The first recognition of the ordinal rank of the Cardiodont reptiles was offered by Owen in 1859, when he proposed for them the name Opisthocœlia, as one of three suborders of crocodiles. The group was characterized as follows:[†] "The small group of Crocodilia, so called, is an artificial one, based upon more or less of the anterior trunk vertebræ being united by ball-and-socket joints, but having the ball in front instead of, as in modern crocodiles, behind. Cuvier first pointed out this peculiarity in a crocodilian from the Oxfordian beds at Honfleur and the Kimmeridgian at Havre. The Reporter has described similar opisthocœlian vertebræ from the Great Oölite at Chipping Norton, from the Upper Lias of Whitby, and of much larger size, from the Wealden formations of Sussex and the Isle of Wight. These specimens probably belonged, as suggested by him in 1841 and 1842, to the fore part of the same vertebral column as the vertebræ, flat in the fore part and slightly hollow behind, on which he founded the genus *Cetiosaurus.*"

In this classification Owen was followed by Haeckel, but Huxley, in the following year, included *Cardiodon* in the Iguanodontidæ. In 1874 Seeley, describing the genus *Craterosaurus*, proposed for the same forms the order Cetiosauria, which he included under the subclass Dinosauria:[‡] "My fossil presents some remarkable differences from other figured Dinosaurian specimens, and I have thought it worthy of the attention of the Society, as indicating that distinct ordinal groups are probably confounded under the name Dinosauria. For if the skull be Dinosaurian which was figured by Mr. Hulke as probably that of *Iguanodon* (and of its Dinosaurian character I entertain no doubt), and the specimen now described be Dinosaurian, in the ordinary sense of the term, as I believe, then no one will doubt the propriety of placing the latter animal, with its indisputable lacertian characteristics, in a distinct ordinal group from the Wealden animal, which has the skull closed anteriorly in a way to which no Lacertilian makes an approximation.

"This difference is, indeed, in harmony with lacertian differences n portions of the skull in *Cetiosaurus;* so that had there been any reason for suspecting that the Potton fossil belonged to the Cetiosauria, I should have felt no difficulty in regarding it as the base of a Cetiosaurian cranium. . . . . On the whole, I regard the bone as indicating that in at least one Order of the Sub-class Dinosauria the bones of the base of the cranium were Rhyncocephalian rather than Avian."

---

[*] In a recent publication by Lucy P. Bush *Cardiodon* is shown to have priority over *Cetiosaurus.* Am. Jour. Sc., Vol. xvi, p. 96.

[†] Report British Association for the Advancement of Science, 1859, p. 164.

[‡] Q. J. G. S. of London, Vol. xxx, p. 690.

In 1878 Marsh proposed to raise his previously established group Atlantosauridæ to the rank of suborder, and to include in it the genera *Atlantosaurus*, *Apatosaurus*, *Morosaurus*, and *Diplodocus*.* The suborder was clearly defined with regard to American groups, but the European forms and their previous classification were ignored, although a number of them clearly fall within the same family groups.

In this way these three synonymous terms have been adopted and used by various writers. "Opisthocœlia" has the undisputed claim to priority. As applied, it included as its characteristic representative *Cardiodon*, the best known of the European forms. In its primary significance it is descriptive of all the well known forms, both European and American, which have since been included in the group. It was followed by Haeckel and in part by Cope and Baur. The one objection which has been urged against the term is, that it was proposed to be applied to a subdivision of the Crocodilia. This objection is not valid, since there are no opisthocœlous crocodiles with which the group can be confused. The homogeneity of the group according to the first definition was recognized when it was bodily transferred by Seeley into the Dinosauria, when it was defined as Sauropoda by Marsh, and when it was made an independent order by Baur. Its inclusion under the Crocodilia was designated at the outset as artificial; its present inclusion under the Dinosauria was regarded by Baur as equally artificial. If this be true, the same objection will hold against the terms later applied.

The term "*Cetiosauria*" has gained favor owing chiefly to the fact that it was offered as a subdivision of the Dinosauria and hence has coincided more nearly with later classification. It was based upon a distinction between the Cetiosaurian and Iguanodon skull, but that distinction had been taken for granted by earlier writers, and was only made necessary by Huxley's erroneous reference of *Cardiodon* to the Iguanodontidæ.

As regards the term "Sauropoda," it must be recognized that it was based upon a much more complete knowledge of the group, and as a result was much more clearly defined. But if we were to demand complete knowledge of structure and affinities, in support of a group name, very few genera and families now accepted would stand.

---

* Am. Jour. Sc., Vol. xvi, p. 412.

The three terms, then, are essentially co-ordinate and co-extensive. "Opisthocœlia" has priority, and is entitled to preference. The term will therefore be used in this paper to designate the order; "Cetiosauria" and "Sauropoda" being regarded as synonyms.

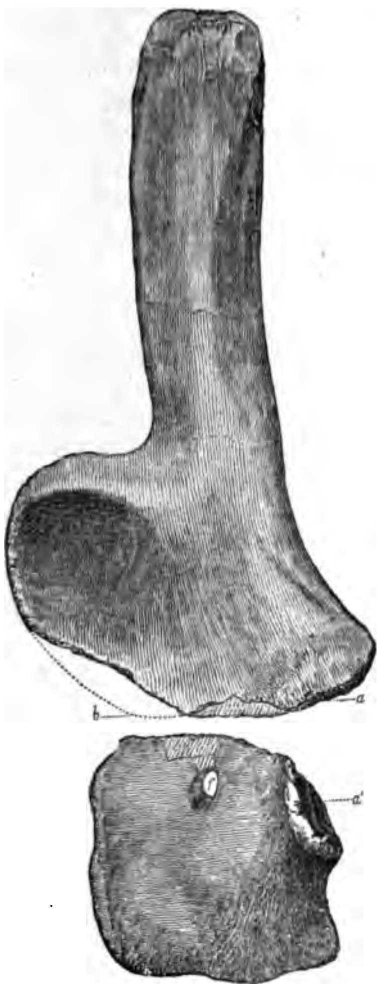


FIG. 1. Scapula and coracoid of *Apatosaurus*, after Marsh.

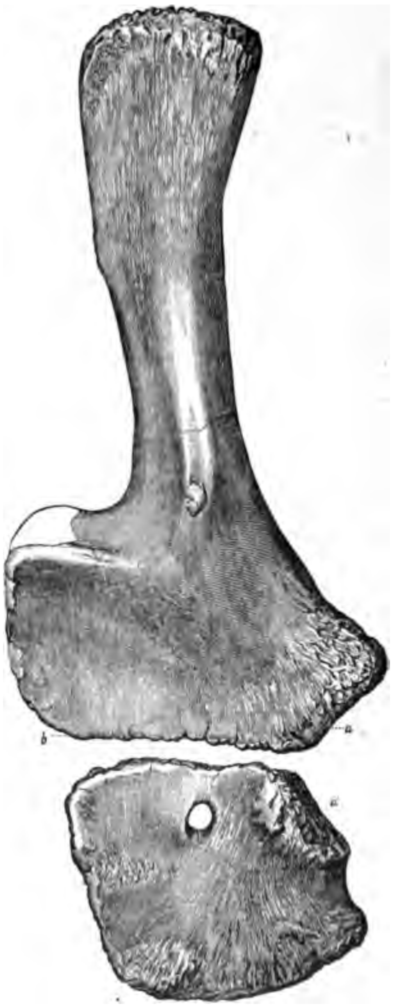


FIG. 2. Scapula and coracoid of "*Brontosaurus*," after Marsh.

The genus *Apatosaurus* Marsh was proposed in 1877 upon a considerable portion of a skeleton, but with brief description only.* Early in 1879 the genus was characterized by the structure of the scapula, coracoid, and sacrum, and these parts were figured.* In December of the same year the genus *Brontosaurus* was proposed upon an unusually complete specimen briefly described.† Later a more complete description was given and a number of parts figured.‡ Two different restorations were later published.§

---

* Am. Jour. Sc., 3d Ser., Vol. xiv, p. 514.

The genus *Brontosaurus* was based chiefly upon the structure of the scapula and the presence of five vertebræ in the sacrum. After examining the type specimens of these genera, and making a careful study of the unusually well-preserved specimen described in this paper, the writer is convinced that the Apatosaur specimen is merely a young animal of the form represented in the adult by the Brontosaur specimen. As before pointed out,‖ the imperfectly ossified condition of the scapula, coracoid, and sacrum indicates a young animal. (Figs. 1 and 2.) The presence of but three coalesced vertebræ in the sacrum points to the same conclusion as will appear from a comparative study of sacra offered in this paper. The proportionate size of the two specimens, the shorter shaft and narrow distal end of the scapula, the outline of the coracoid, the open chevrons, the form of the anterior thoracic and the cervical vertebræ, and the structure of the pelvis (Figs. 3 and 4) all display such similarity as one would expect in a young animal of the Brontosaur type. In fact, upon the one occasion in which Professor Marsh compared ¶ these two genera he mentioned the similarity between the scapulæ of their respective types. In view of these facts the two genera may be regarded as synonymous. As the term "Apatosaurus" has priority, "Brontosaurus" will be regarded as a synonym.

The following species have been referred to this genus:

A. ajax Marsh, type of genus, Am. Jour. Sc., (3), xiv, 514, Dec., 1877.

A. grandis Marsh, ibid., (3), xiv, 515, Dec., 1877.
  Referred to *Morosaurus*, ibid., (3), xvi, 414, Nov., 1878.

A. laticollis Marsh, ibid., (3), xvii, 88, Jan., 1879.

A. excelsus Marsh, ibid., (3), xvii, 503, Dec., 1879.
  (*Brontosaurus excelsus*) this paper.

A. amplus Marsh, ibid., (3), xxi, 421, May, 1881.

Of this number probably not more than two species are valid. *A. ajax* is based upon a specimen too young to admit of specific determination. *A. grandis* is a synonym. *A. laticollis* was described

---

* Ibid., Vol. xvi, p. 86.
† Ibid., 3d Ser., Vol. xviii, p. 501.
‡ Ibid., 3d Ser., Vol. xxi, p. 417-21.
§ Ibid., 3d Ser., Vol. xxvi, Pl. 1; The Dinosaurs of North America, Pl. XLII.
‖ Am. Jour. Sc., 4th Ser., Vol. xv, p. 305.
¶ The Dinosaurs of North America, U. S. Geolog. Surv., Vol. xvi, p. 168.

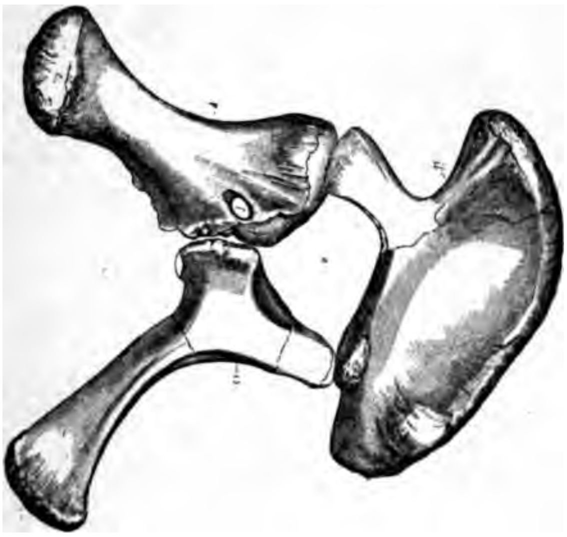


FIG. 3. Pelvis of *Apatosaurus*, after Marsh.

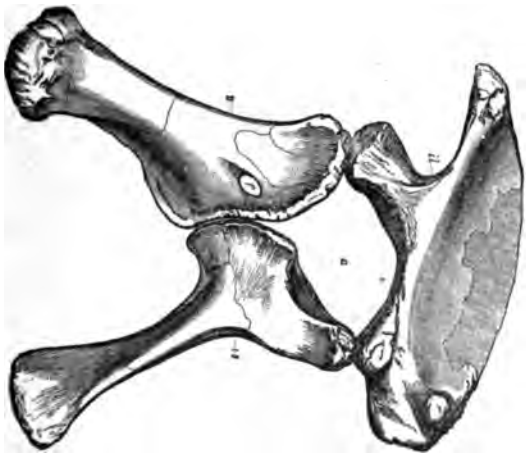


FIG. 4. Pelvis of "*Brontosaurus*," after Marsh.

from a single cervical vertebra which may or may not be identical with the type species. *A. excelsus* is familiar as the type of "*Brontosaurus*," and is based upon a large part of a skeleton. The sixth and the last cervical vertebræ of this specimen as figured by Marsh* show such a similarity to the type of *A. laticollis* as to indicate that the intervening ninth or tenth vertebra would prove identical. However, the present knowledge of the cervical series does not admit of positive identification. *A. amplus* has not been figured and cannot now be determined. The Museum specimen will be regarded as conspecific with the well known Yale specimen and designated as *Apatosaurus excelsus*.

The genus *Apatosaurus* may be distinguished from other members of the Opisthocœlia by the following characteristics: Scapula with shaft and spine almost at right angles; shaft long and slender with slightly expanded distal end; ischium with acetabular surface at right angle to shaft and distal end expanded; sacrum in adult specimens with five ilium-supporting vertebræ; anterior dorsal spines paired, long, and slender; anterior caudal centra with lateral cavities.

DESCRIPTION OF SKELETON.

DORSAL VERTEBRÆ. (Plates XLVI and LII.) The vertebræ lying between the cervical and the sacral regions are all rib-bearing, and hence may be designated by the term "dorsal"; but in the following description they will be referred to as "presacral" and numbered from the sacrum forward in order to afford a definite basis of reckoning, since the fragmentary condition of presacral XI does not admit of its position in the series being determined with absolute certainty. However, there is every reason to believe that this vertebra is the last cervical.

The *dorsal vertebræ* are of the opisthocœlous type, and are all rib-bearing. So much may be said of them as a group—as to other characteristics they represent a continuous transition, passing from the elevated and slender type posteriorly to the depressed and wide-armed type of the anterior dorsal region. In view of this wide difference between the anterior and posterior extremes of the series, it is not surprising that isolated vertebræ have been made the types of three or more different genera. Variation between the extreme types of the dorsal series is especially noticeable in the following four vertebral elements. (1) The centra, (2) the neural spines, (3) the transverse processes, and (4) the capitular facets. In order to bring out their gradation, the vertebræ will be described by taking up the several elements in turn and tracing them through the entire thoracic series.

---

* Plates XX and XXI, the Dinosaurs of North America.

The *centra* pass from the less pronounced opisthocœlous type near the sacrum to the pronounced type of the cervical region. In the first presacral the vertical diameter of the centrum is equal to the lateral diameter; as we pass forward in the series the centra become vertically compressed while the lateral measurement remains approximately the same. The articular ends from I to VIII are nearly perpendicular to the axes of the centra; with IX the articular surface begins to incline forward, this feature becoming more and more pronounced until the centra take on the cervical type with presacral XI. The openings of the pleuro-central cavities in the first presacral are almost round and enter the centrum from above downward. With the strengthening of the pedicles and the depression of the centra, these assume a lateral direction. In the anterior members of the series they become elongate axially; in IX and X they are partially replaced by the capitular facet.

In cross section the typical centrum shows an external wall pierced by two lateral foramina leading to the pleuro-central cavities, which are separated by a thin median septum. This arrangement is, however, subject to regional modification. In the first presacrals there are a number of vacuities in the inferior portion of the centrum which do not connect with the lateral fossæ. In I these consist of small cavities within the posterior rim of the centrum; in II the cavities are large and occupy the lower half of the centrum, being separated from the lateral fossæ by a wall two centimeters in thickness.

The *transverse processes* arise from four roots: (1) a horizontal plate which extends laterally from the prezygapophysis; (2) a second horizontal plate which arises from the anterior margin of the postzygapophyses and passing forward unites with the posterior margin of the first; (3) a vertical plate which arises from the base of the pedicle, passes upward and forward, and fusing with the inferior surface of the lateral plate, forms a bracket-like support below; (4) a similar but smaller vertical plate which arises from the lateral surface of the neural spine, passes outward and unites with the superior margin of the horizontal plate, supporting it from above. With the reduction and bifurcation of the spine, the superior root becomes reduced, shifted backward, and in VI joins the posterior root. In IX and X it is absent entirely. With the depression of the capitular facet, a second anterior root makes its appearance in V. This arises from the lateral surface of the capitular process and is noticeable as a slight ridge just below the anterior margin of the horizontal plate. In VI this remains very slight; in vii it is shifted downward forming a median brace between the anterior and the inferior roots; in viii it appears as an anterior brace to the side of the inferior root; in ix and x it descends quite to the anterior margin of the centrum and forms a second inferior support equal in importance to the first.

The *tubercular facets* are borne low on the extremities of the transverse processes. They are irregularly concave and vary in size according to the strength of the ribs which they bear. In presacrals i to viii they face outward and slightly downward; in ix and x their direction is altered so as to face more downward than outward.

The *neural spines* undergo a radical transformation in the dorsal region. (Plate xlvi.) The posterior members of the series represent the extreme development of the straight, median spine. From this point to the eleventh presacral, or first cervical, they pass by a regular gradation from the simple to the bifurcate. This change is so regular that no point in the series can properly be designated as "nodal" but at the same time all are transitional. In presacrals i, ii, and iii the spines are similar in length to the anterior sacral. In iv there is a noticeable shortening supplemented by a slight concavity on the anterior margin of the crest, which marks the first tendency toward bifurcation. In v and vi this concavity is deepened and the spine reduced in the latter to little more than half the length of that in iii. At the same time it has increased in breadth and the lateral angles of the crest have become acute and somewhat produced. Each of the lateral plates give rise to two diagonal branches; the median plate is noticeably reduced. In vii the anterior aspect of the spine presents a broad, flattened surface. The median plate is reduced to a mere rugose ridge on the anterior surface; posteriorly it is somewhat more marked. The lateral angles of the crest are extended, forming a pair of lateral processes surmounted by laterally flattened crests. However, the vestigial median plate still furnishes the chief anchorage for the dorsal muscles. In viii the median concavity descends to a level with the superior margin of the post-zygapophyses. The median plate is reduced to a mere roughening for muscular attachment which persists to the end of the series. Bifurcation may thus be regarded as complete. The spines in ix and x are slight and deeply excavated at their bases by lateral vacuities.

The *post-zygapophyses* are supported inferiorly by a pair of buttresses arising from the posterior surface of the neural arch, laterally by the posterior roots of the transverse processes, and superiorly by a second pair of buttresses descending from the lateral plates of the neural spine. In the posterior dorsal vertebræ the superior buttresses trong, but with the bifurcation of the spine they become reduced, are replaced by a second short, stout pair which meet in the an line. In presacral i the articulating surfaces are concave and downward to articulate with the prezygapophyses of the first ıl; in the succeeding vertebræ they face outward and downward ıe form of a wide V. At the point of convergence the articular ces are expanded into a prominent hyposphen. This is supported below by a second pair of buttresses arising from the neural In presacral vii both zygapophyses and hyposphen reach their ıgest development. In ix the hyposphen disappears entirely; in zygapophyses are more elevated and widely separated.

The *prezygapophyses* are supported chiefly by a single stout pair of esses arising from the anterior margin of the pedicles. Their ulating surfaces are directed upward and slightly inward. In the ior members of the series they are separated by a narrow notch, ypantrim, into which the hyposphens of the preceding vertebræ In viii there is a pronounced widening of this notch correspond- vith the disappearance of the hyposphen from ix. In ix and x rezygapophyses are still more widely separated.

The *capitular facet* varies much, both in strength and in position, ıe vertebra, as we pass forward in the dorsal series. (Plate lii.) the facet is very slight; it arises by three roots from the inferior ce of the prezygapophyses and from the lateral surface of the neural It increases in strength in v and vi, and is slightly depressed by hortening of the pedicles. In vii the decided shortening of the les brings the inferior border of the facet almost to the margin e centrum. The facet itself is more than double the size of that . In viii it is shifted downward so that half of its articular sur- springs from the centrum. In ix the facet is borne entirely on entrum just anterior to the lateral fossa and partially replacing it. the transposition is complete, the facet having passed entirely v the anterior end of the lateral fossa. In the last two vertebræ also much reduced in size.

MEASUREMENTS OF PRESACRAL VERTEBRÆ IN CENTIMETERS.

PRESACRAL VERTEBRA	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Height over all at median line	1.34	1.31	1.29	1.20	1.06	.88	.72	.58	.53	.49	**.40
Breadth across transverse processes	*.74	*.67	.73	.78	.86	.92	1.01	1.13	1.12	1.14	--
Centrum, length of	.25	.25	*.30	*.26	.28	.29	.29	.33	.36	.37	.44
Centrum, breadth at posterior end	.40	.41	.41	.40	.41	.40	.41	.41	.40	.40	.41
Centrum, vertical diameter at posterior end	.41	.39	.37	.34	.30	.29	.29	.28	.28	.27	.25
Centrum, depth of posterior concavity	.06	.07	.07	.07	.06	.07	.07	.09	.12	.14	.15
Spine, height above centrum in median line	.96	.94	.95	.90	.79	.60	.45	.28	.25	.21	--
Spine, greatest antero-posterior diameter of median plate	.19	.18	.18	.20	.20	.17	.09	--	--	--	--
Spine, length of lateral spines from concavity at median line	--	--	--	—	.13	.19	.29	.43	.46	.40	--
Spine, lateral breadth at crest	.17	.18	.19	.19	.24	.34	.46	.59	.62	--	--
Prezygapophyses, breadth across articulating surfaces	.35	*.33	.35	.35	.34	.35	.44	.54	.58	.57	.59
Prezygapophyses, distance between articulating surfaces	*.01	*.01	.03	.04	.04	*.02	.05	.14	.17	.23	.25
Postzygapophyses, breadth across articulating surfaces	.34	.35	.35	.35	.29	.29	.37	.43	.51	.56	.58
Capitular facet, height of inferior surface above centrum	.20	.24	.22	.18	.19	.19	.06	.00	—	--	—

*Modified by distortion. **Measurement estimated.

THORACIC RIBS.

Eighteen ribs, more or less complete, are preserved with this specimen. Ten of these belonging to the right side form a continuous series in which the first and last are so reduced in size as to indicate that the series is complete. Those of the left side correspond very closely with the right, except that the third and fourth have been carried away entirely. This number of ribs, preserved so nearly in their normal positions, may be regarded as conclusive proof that there were but ten vertebræ in the dorsal series.

In the *first pair* of ribs more than half of the distal ends were eroded away. The head and the tubercle are slender and divergent; the shafts taper toward the distal end and are too slender to have performed any important function. (Plate XLVII.) The second pair of ribs is considerably stronger than the first. Only the proximal half of the right and the head of the left are preserved. At this point the divergence of head and tubercle is most pronounced, the head forming an angle of sixty-five degrees with the shaft. The third and fourth pairs of ribs are the strongest of the series. The articular facets are broad and rugose, and stand at almost a right angle to the shaft. The proximal ends are expanded and massive, bearing trough-like fossæ on their mesial surfaces. The distal ends are missing from both.

The *fifth pair* of ribs is complete and well preserved. The head is more elongate, indicating greater expansion of the thorax at this point. The distal end bears a broad and roughened surface for the attachment of the costal cartilage. The right member of this pair is of interest in having an enlargement in the shaft, due to an imperfectly healed fracture. The adjoining sixth rib has a similar fracture which failed to heal. The sixth pair is marked by a decided reduction in size, a noticeable shortening, and a slender and tapering distal end. The head continues to elongate, the tubercle to shorten. In the seventh and eighth pairs the shafts become shorter and slighter, and the head more elongate. In the ninth the head and tubercle are quite reduced and the shaft is more curved at the proximal end. The tenth pair is reduced to mere rudiments whose shafts are almost lost. The right one has coössified with the vertebra by the head and tubercle while the distal end has a flattened surface which abutted the crest of the ilium.

MEASUREMENTS OF RIBS.

RIB NUMBER	I	II	III	IV	V	VI	VII	VIII	IX	X
Length	-	--	---	---	2.13	2.07	1.85	1.70	1.26	.62
Breadth across head and tubercle	.430	.510	.500	.440	.405	.420	.360	.310	.250	.240
Breadth of shaft at middle	.080	.095	.130	.130	.125	.085	.090	.085	.080	.060

SACRAL VERTEBRÆ.

The sacrum in this specimen is composed of five vertebræ, coalesced by the centra, zygapophyses, and more or less by the sacral ribs. The second, third, and fourth vertebræ are in addition firmly conjoined by their neural spines, the crests of their neural arches, and the bases of their diapophyses. Their sacral ribs unite distally to form a yoke-like synostosis, which, in the Opisthocœlia, may fittingly be termed the sacricostal yoke. This is approximately symmetrical to the transverse axis of the sacrum and is borne upon the rim of the acetabulum, which constitutes its chief support. These three vertebræ have been described[*] by Osborn in "Camarasaurus" and by Williston in Morosaurus[†] as constituting the primitive sacrum. They will therefore be designated in this paper as the primary sacrum, but in the series of vertebræ functional as sacral, or ilium-supporting vertebræ they will be numbered two, three, and four. The first vertebra which functions as a sacral, but varies in the structure of its sacral rib, will be termed the dorso-sacral. In like manner the fifth of the series will be termed the caudo-sacral. (Plate XLVIII.)

The dorso-sacral bears evidence of having united with sacral II by its centrum and zygapophyses before adult age. The sacral ribs show a degree of coössification similar to that between the sacral ribs and the right ilium. The spine remains free, but stands close to the second spine—a condition which would tend to coalition. The caudo-sacral shows even more recent coössification with the primary sacrum. The centra are firmly coössified, the sacral ribs incompletely so; the zygapophyses are conjoined, but little atrophied, the neural spine remains free and isolated. A comparison in structure between this vertebra and the first caudal shows no greater difference than that between caudals I and II.

The centrum in sacral I is not reduced in size and differs from the dorsal centra only in its thicker walls. The anterior end is slightly convex; the lateral cavities open just behind the base of the sacral rib. (Plate XLVIII.) The centra of sacrals II, III, IV are considerably reduced in size and are more firmly united. The pleuro-central cavities open upward, just back of the pedicles. The centrum of sacral V is firmly united with the preceding one, but is not reduced in size and is little excavated by lateral cavities. The posterior surface is quite concave in its lower half, the margin slightly receding above.

The *neural arches* begin with the dorsal type in sacral I; in II, III, and IV they are drawn together antero-posteriorly and conjoined from the neural canal upward, leaving vertically elongate vacuities opening into the enlarged intervertebral chambers of the neural canal. In IV and V the neural arches are shifted forward so as to overhang the intercentral sutures. The prezygapophysial articulation between I and II is atrophied but still in evidence; that between II, III, and IV is lost entirely; between IV and V it has become ankylosed but otherwise little modified. The hyposphen-hypantrum articulation persists as far as sacral V. (Plate L.)

---

[*] Bulletin Am. Mus., Vol. x, p. 230.

[†] Kans. Univ. Quarterly, Vol. vii, p. 173.

The *neural spines* of the sacral vertebræ diminish regularly in length from first to last. The spine of sacral I is similar to that of presacral I, except that the forward curvature is nearer the base. The spines of II, III, and IV are firmly united by their median plates and show from their strength and system of bracing that this was the chief anchorage for dorsal and dorso-caudal muscles. The lateral plates in II are more strongly developed than in any other spine; their anterior buttresses which descend to the prezygapophyses are developed into stout braces to resist antero-lateral strain. The posterior roots have disappeared entirely. The lateral plates of III are almost lost; those of IV are well developed and braced in turn by the posterior root, while the anterior one has disappeared.

The *sacral ribs* take the form of stout, blunt processes firmly ankylosed with the centra and expanded distally to articulate with the ilium. Those of the three primary sacrals are similar in general structure, save that the middle one is reduced in size; they coalesce distally to form the sacricostal yoke. The first and second ribs arise from the mid-lateral surface of the centra; the third has its origin at the anterior end of the centrum. The ribs of the dorso-sacral vertebra arise from the antero-superior margin of the centrum in conjunction with the base of the neural arch. They articulate distally with the anterior surface of the great peduncle of the ilium. The ribs of the caudo-sacral vertebra are similar in origin to those of the true sacrals, but are expended distally into oblique plates, which are united with the diapophyses as in the anterior caudals. In this specimen the ribs are imperfectly united with the sacricostal yoke. They articulate distally with the posterior surface of the lesser peduncle and with the mesial surface of the iliac plate. (Plate XLVIII.)

The *diapophyses* show no essential modification from the thoracic type. They are more or less completely connected with the sacral ribs by a thin vertical plate. On the right side of the museum specimen, where the ilium is conjoined, this plate forms a continuous articular surface, connecting the ribs and diapophyses in sacrals I and II, while in III and IV there remain only slight vacuities. In V, as before mentioned, the diapophyses and ribs are united througho In II, III, and IV the merging of the three neural arches, and con quent reduction of space occupied by them in the antero-poster direction, gives to the diapophyses the appearance of radiating fron common center. This feature is accentuated by the general tenden of sacra to be compressed in this direction while in the matrix, owi to the frailty of the arches as compared with the centra. This a accounts for the usual convexity of the inferior outline of the sacra series which should doubtless be concave.

MEASUREMENTS OF SACRUM.

	M.
Length of five coalesced centra	1.260
Height of sacral I over all	1.350
Height of sacral II over all	1.31
Height of sacral III over all	1.23
Height of sacral IV over all	1.19
Vertical diameter of centrum I at anterior end	.36
Lateral diameter of centrum I at anterior end	.38
Vertical diameter of centrum V at posterior end	.37
Lateral diameter of centrum V at posterior end	.36
Breadth of coalesced spines II, III, and IV at crest	.39
Breadth of coalesced spines II, III, and IV at base	.28
Length of spine above prezygapophysis in I	.78
Length of spine above prezygapophysis in V	.69
Length of sacricostal yoke	.65

MORPHOLOGY OF THE OPISTHOCŒLIAN SACRUM.

The composition of the sacrum in various genera of the Opisthocœlia has been regarded from almost as many points of view as ther have been writers on the subject. Marsh looked upon the number o sacral vertebræ as a fixed quantity for each generic group and base many of his genera upon this character. In defining the order "Sauropoda" he characterized the sacrum as composed of not more than fou vertebræ. In later classifications the number of sacrals was not give as an ordinal character. Cope placed less stress upon the number o sacral vertebræ, but used it in generic distinctions.

Osborn, in 1898, described the sacrum of "*Camarasaurus*" a follows: "*Camarasaurus* had five sacral vertebræ; three of these constantly coalesced both by centra and neural spines, two others coalesce less constantly and possessed free spines." * Soon after, Willisto offered the following more general characterization: "It is very clea that there are three typical vertebræ in all the genera of this famil (Camarasauridæ) as well as in the Morosauridæ, if it be a distinc family, all of which present very distinct points of similarity. It is probable, as evidenced by the separated sacral vertebræ in *Morosaurus lentis* that the condition of ossification varies with age, the middle three uniting earliest, the first next, and the fifth last. The slight union of the fifth might, indeed, be absent in the adult without affording generic or even specific characters." *

---

* Bull. Am. Mus., Vol. x, p. 230.

A year later Dr. Osborn wrote of the sacrum of *Diplodocus:* "There are four rib-bearing true sacral vertebræ in *Diplodocus* instead of three, as hitherto described by Marsh. The three anterior sacrals, constituting the primitive Dinosaurian sacrum, are firmly united by their neural spines. These three spines coalesce into a single very robust spine showing the diapophysial laminæ separate."

In his recent monograph on *Diplodocus* Mr. Hatcher described two sacra as follows: "The two splendid sacra belonging with skeletons 84 and 94 in our collections are unusually complete. . . . . In each instance the vertebræ are firmly coössified with and give support to the ilia. In 84 the right ilium alone is preserved and this is united with all five of the vertebræ which function as sacral either by means of true sacral ribs or the expanded diapophysial laminæ or by both these elements. All are coössified by their centra and the three median have their spines coalesced. . . . . In skeleton 94, however, there are noticeable certain other more marked differences which are worthy of special notice as bearing directly upon the nature of the primitive inosaurian sacrum. In this skeleton the sacrum is present, with oth ilia in position. The centra of the true sacrals are all coössified s in other sacrum. The neural spines of sacrals one and two coalesce nd are coössified throughout their entire length as in 84, but the spine sacral three is quite free from, though closely applied inferiorly to, at of the second sacral. This would seem to indicate that the prim- ve Dinosaurian sacrum consisted of two rather than three vertebræ, condition found in the Crocodilia and most other living Reptilia. e fourth sacral in No. 94 bears a free spine and is coössified by its ntrum with the third and does not differ in any essential respect from t described by Osborn or from that found to obtain in No. 84 of collections."

From the above it will be seen that Osborn and Williston agree n the structure of the primitive sacrum as indicated by "*Camara- us*" (Apatosaurus), *Morosaurus*, and *Diplodocus.* This is based n the tendency of the median three vertebræ to unite by spines and . Hatcher has dissented from this opinion, postulating that the itive Dinosaurian sacrum consisted of no more than two vertebræ.

---

* Kans. Univ. Quarterly, Vol. vii, p. 173.

This conclusion is based upon a single sacrum of *Diplodocus;* a second sacrum referred to the same species and described in the same paper agrees with the usual type in having the spines of sacrals II, III, and IV coalesced. The sacrum just described in this paper also agrees in the same particular.

It will be observed that there is a considerable variation in the coössification of various elements in the Opisthocœlian sacrum, which cannot be attributed to age. By comparing the composition of known sacra of *Apatosaurus*, *Diplodocus*, and *Morosaurus*, it will be seen that there is a noticeable similarity in the development of that of the former two, while the latter stands quite aloof. This is well represented by the accompanying diagrammatic figures.

The *Apatosauroid sacrum* is represented by four, possibly five, known specimens. The most primitive composition is found in the young specimen in the Yale University collection, well known as the type of *Apatosaurus*. In this sacrum only the three primary centra with their coalesced ribs are preserved (Fig. 5). A second specimen, described by Dr. Osborn as Camasaurus,[*] has, according to his description, the three primary centra coalesced by spines and sacral ribs as well as by the centra (Fig. 6). The dorso- and caudo-sacrals are both free; the latter, though structurally a caudal, was functional as an ilium-supporting vertebra. These characteristics as well as the size of the animal indicate that it was not quite adult. A third specimen in the Carnegie Museum figured[†] by Mr. Hatcher as "*Brontosaurus*," may or may not belong to this genus (Fig. 8). The figure shows that the primary sacrals have their spines coalesced as in the typical adult. The caudo-sacral is firmly conjoined by centrum, ribs, and diapophyses as is the centrum of the dorso-sacral. The first caudal is also conjoined, at least in part.

The unusually well preserved sacrum in the Museum specimen may be taken as a typical representative of the adult of this genus. In this, sacrals II, III, and IV are firmly conjoined by centra, neural arches, sacral ribs, and bases of the diapophyses (Fig. 7). The centra, sacral ribs, diapophyses, and lateral spinous plates are more or less reduced from loss of function. The zygapophyses and zygosphenes are no longer traceable. The dorso-sacral is firmly coalesced by centrum and zygapophyses; the ribs are partially conjoined, the spine is free, but stands close to that of sacral II. The caudo-sacral is a typical anterior caudal coössified by centrum and zygapophyses, and partially by the ribs. The spine is free and isolated. The right ilium

---

[*] *Loc. cit.*

[†] Memoirs of the Carnegie Museum, Pl. x, Fig. 3

APATOSAUR SERIES.

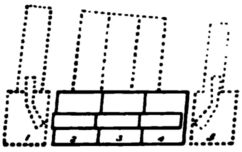


Fig. 5.

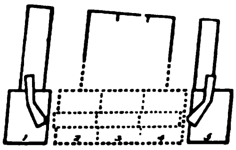


Fig. 6.

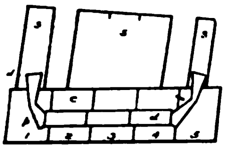


Fig. 7.

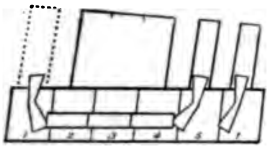


Fig. 8.

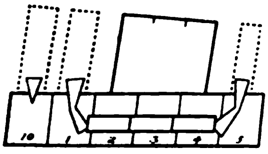


Fig. 9.

DIPLODOCUS SERIES.

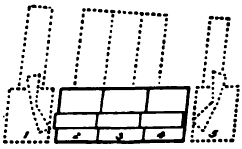


Fig. 10.

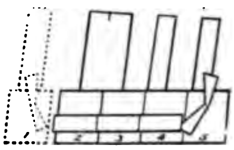


Fig. 11.

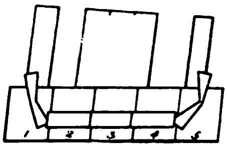


Fig. 12.

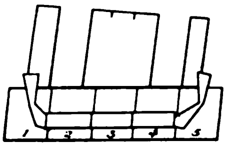


Fig. 13.

MOROSAUR SERIES.

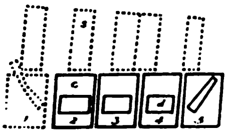


Fig. 14.

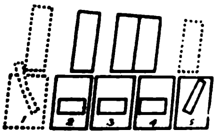


Fig. 15.

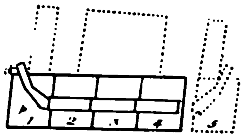


Fig. 16.

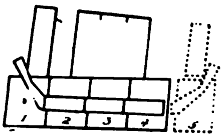


Fig. 17.

Diagrams illustrating the structure of the Opisthocœlian Sacrum.

is coössified by all of the ribs and diapophyses, the left evide remained free. The type specimen of "*Brontosaurus*" is similar far as can be determined, except that the first presacral is also c joined (Fig. 9).

This series shows just such a development as one might expect passing from a two-thirds grown animal to one of advanced age. Th additional dorsal vertebra united with the sacrum in the type specime of "*Brontosaurus*" and the additional caudal united in the Carnegi Museum specimen, are but further evidence of the persistent tendency of adjacent vertebræ to coössify with the sacrum in animals of advanced age.

The four known sacra of *Diplodocus* show a very similar developmental series. The sacrum of *D. longus*, figured by Marsh, has only three vertebræ coalesced by centra and by sacral ribs (Fig. 10). The posterior end of the sacricostal yoke shows a facet for the caudo-sacral rib. The Carnegie Museum specimen No. 94 has vertebræ II, III, IV, and V coalesced by the centra, II, III, and IV by the ribs, and II and III by the spines. The dorso-sacral remains free (Fig. 11). The American Museum specimen has an arrangement similar to that of the adult *Apatosaurus*, except that the sacral rib in the dorso-sacral is less strongly developed (Fig. 12). The Carnegie Museum specimen No. 84 is described as having this rib more nearly functional (Fig. 13).

The *Morosaur sacrum* is known to the writer from four specimens. The type of *M. lentus* has four disarticulated sacral centra, each of which bear functional ribs not united with the centrum (Fig. 14). The neural arches are likewise free from the pedicles. The neural arch and spine figured with the posterior centrum in this specimen, and which has long been called in question, belongs with a caudal vertebra. This is proved beyond question by an almost identical specimen in this Museum.

The Morosaur sacrum No. 5384 of the Museum has centra II and III, and IV and V, united in pairs (Fig. 14). The ribs are free from the centra as are the neural arches. The spines of II, III, and IV are imperfectly coössified by their zygapophyses. The specimen indicates an animal little more than half grown. A third Morosauroid sacrum in the University of Kansas (figured by Williston *loc. cit.*) has vertebræ I, II, III, and IV united by centra, spines II, III, and IV coalesced and the sacral ribs of the same united to form the sacricostal yoke (Fig. 15). The broad rib of the dorso-sacral is firmly united with this yoke and there is a blunt posterior projection from the fourth rib indicating that it abutted against the rib of the caudo-sacral which in this form has not been found conjoined. This specimen agrees very closely with the type of *M. grandis* so far as it will admit of determination. The Morosauroid sacra thus appear to fall into two groups. The first, as indicated by the type of *M. lentus* and No. 5384 of this Museum, has the dorso-sacral free. The second, as represented by the type of *M. grandis* and the Kansas University specimen, has the caudo-sacral free. A more important difference is that in the sacra of the former type the transverse axis passes between sacrals III and IV, while in the latter it passes through sacral III as in *Apatosaurus* and *Diplodocus*. If this feature proves constant it would indicate generic differences.

From the above it will be observed that the sacra of *Apatosaurus* and *Diplodocus*, so far as can be traced from the young animal to the adult, develop along similar lines. In Apatosaurus sacrals II, III, and IV coalesce first as is shown by the two young specimens (Figs. 5 and 10), by the closer union of all the elements of these same vertebræ in the adult specimens (Figs. 7, 8, and 9), and by the noticeable tendency of articulating parts to atrophy from disuse. Sacral I usually unites next, and V last, as shown by Figs. 6, 7, and 8, although this order may sometimes be reversed, as is shown by Fig. 9. Coalition may be carried even farther, as appears by the union of Caudal I in Fig. 7 and presacral I in Fig. 9. In *Diplodocus* the same order is noticeable with the exception pointed out by Mr. Hatcher (Fig. 6), in which sacral I and the spine of IV remain free in a specimen apparently adult, while sacral V is coössified by its centrum. However, this is a variation similar in kind to that noted in *Apatosaurus*.

The above deductions carry out, for these two genera, the theory advanced by Osborn and supported by Williston, namely: That sacrals II, III, and IV represent the primitive sacrum. But how far back in the history of the group these conditions may have held, remains a question. If we assume that the Opisthocœlia are derived from a bipedal ancestry, which were in turn derived from a crawling ancestor, we may explain the condition as follows:

It has been observed that the transverse axis of the pelvis passes through the ribs of sacral III. This would be the natural point for the pelvis to attach to the vertebral column in a terrestrial animal where the thrust of the femur is upward. The fact that sacral III has its centrum, ribs, diapophyses, zygapophyses, and neural spine most reduced indicates that it formed the primitive sacral center. Such an attachment doubtless served the primitive crawling reptilia, but as specialization in terrestrial habits progressed, and there was need of a more rigid pelvic structure, sacrals II and IV probably became conjoined, one after the other. In this way the sacrum *developed* by alternating additions on each side of the axis just as the perissodactyl foot in mammals has been *reduced*. With these three vertebræ united to form the sacricostal yoke the ilium attained a firmness adapted to terrestrial habits, and yet sufficiently mobile for bipedal locomotion. If we may assume that the Opisthocœlia have passed through such a stage, this would account for the sacrum having become stable at this point in its development. If the form of the ilium had by that time become fixed, the sacrum would have been structurally complete. But with adaptation to quadrupedal habits, and the attendant increase in size, the need of a mobile sacrum was replaced by the demand for greater rigidity. In this way a fourth and fifth sacral, with occasional supernumeraries have been added.

MODIFICATION IN THE LAST PRESACRAL VERTEBRÆ.

The probability that the Opisthocœlian sacrum has expanded by the addition of presacral vertebræ in front, as well as the addition of caudals in the rear, has been doubted by some later writers. The following features in the specimen under consideration are of interest as bearing directly upon this question:

1. The last pair of presacral ribs tend to coössify with the vertebra by both head and tubercle.
2. The distal end of the right rib abutted the inner angle of the iliac crest and was evidently attached to it.
3. The position of the capitular attachment of the ribs passes by regular gradation from the lateral surface of the centrum in sacral II, to its extreme elevation on presacral II.
4. The capitular and tubercular elements, as well as the line of union with the diapophysis, can be traced in the rib of the dorso-sacral.

The *last presacral rib* on the right side of the Museum specimen is firmly coössified by both head and tubercle. The left one is less completely so, although the process has gone far enough to have quite obliterated the articular facets. The shaft of the right rib, unlike that figured by Hatcher in *Diplodocus*, is barely long enough to reach the anterior margin of the ilium. The distal end bears an oblique facet, which evidently abutted the inner angle of the iliac crest. There is no evidence of coössification and no corresponding facet on the ilium. As imbedded in the matrix, the end of the rib had slipped a few inches past the ilium, and the side of the shaft still bears an indentation caused by contact with the angle of its crest. An even more pronounced instance of modification in a presacral rib was noted by Dr. Williston in a specimen of *Morosaurus* in the Kansas University Museum. In this case the distal end of the rib had become expanded and was received by a distinct facet on the mesial angle of the ilium.

In this coössification may be recognized the initial stage of the conversion of a presacral rib into an ilium-supporting element. As the head and tubercle united with the vertebra and became immovable, and the distal end came in contact with the ilium, ligamentary attachment would naturally result. Consequent stress upon the attached rib would lead to specialization in order to meet the new function laid upon it.

The *dorso-sacral rib* bears evidence of just such a modification, which has been carried much farther (Fig. 1, Plate XLVIII). The diapophysis of the vertebra has been considerably reduced and overlaps the tubercular portion of the rib with which it has fused. The latter articulates distally with the crest of the ilium. The head of the rib has fused completely with the parapophysis at the latero-superior angle of the centrum. The distal portion of this element of the rib probably forms the stout process which abuts the great peduncle of the ilium, although this cannot be positively determined from the specimen under consideration. But there can be no doubt that the dorso-sacral of this genus is a modified presacral vertebra.

The position of the capitular attachment of the ribs on the lateral surface of the vertebral centra, as observed in the anterior dorsals, sacrals, and caudals, is evidently the primitive one. From that point the facets have been thrust upward by the dilation of the posterior thoracic and floating ribs. The position of the capitular attachment at the superior angle of the centrum in the dorso-sacral vertebra implies that the rib has either become fixed in its acquired function at a period in ancestral development, when the attachment of the last rib had reached this point in its upward progress, or that, having been elevated, it was again depressed in order to meet the stress of this new function. The amount of modification in the spine, zygapophyses, and centrum of this vertebra indicates that its union with the sacrum has taken place at a comparatively recent period.

CAUDAL VERTEBRÆ.

The series of caudal vertebræ as represented by the Museum specimen is not essentially different from that figured in Marsh's restoration of "*Brontosaurus.*" (See Plate LII.) Dr. Osborn has insisted * that eight or ten of the anterior vertebræ were omitted in Marsh's restoration, and has also estimated † that seven anterior vertebræ were missing from the American Museum specimen No. 222, described by him as *Camarasaurus*. In this he has evidently fallen into error from mistaking sacral v for caudal I and from comparing the caudal series of this form with that of *Diplodocus*. (See Figs. 11 and 12, Plate XLVII.)

---

* Memoirs of the American Museum of Natural History, Vol. i, Part v, p. 213.

† Bull. Am. Mus. of Nat. Hist., Vol. x, p. 224.

As neither of the three caudal series above mentioned is complete distally they offer no positive basis of comparison as to number of vertebræ. In the Museum specimen the number of anterior caudals bearing ribs is twelve, that figured in the Yale specimen is the same, while the number observed by the writer in the American Museum specimen (exclusive of sacral v) is eleven. The diapophyses disappear in the Museum specimen and in the Yale specimen in caudal V; in the American Museum specimen they disappear in caudal IV. The number of anterior vertebræ having lateral cavities in the centra is five in the Museum specimen as compared with three described by Marsh in the Yale specimen. While the point of disappearance of such a vestigial element as the caudal rib cannot be regarded as constant, and the presence of lateral cavities in the centra is even more variable, the fact that these points in Marsh's restoration agree so closely with the Museum specimen indicates that the restoration is approximately correct in this particular. On the other hand, there is probably not more than one anterior caudal vertebra missing from the series in the American Museum specimen.

The *first caudal* vertebra has a number of characteristics which at once distinguish it from other members of the series. Most noticeable among these is the anterior articulating surface of the centrum, which is concave in its upper half, but convex below. The interior of the centrum contains numerous small cavities, the pedicles are hollow, the base of the spine is complicated by numerous infoldings of the peripheral lamina, the sacral ribs are expanded into broad, lateral wings coössified with the diapophyses by a thin vertical plate thickened and rugose at its lateral border; the prezygapophyses face upward as well as inward, and are excavated at their bases by deep lateral fossæ.

Each of the anterior caudal vertebræ bears a pair of lateral plates which project from the surface of the centrum, the neural arch, and the base of the spine. These are made up of two elements: (1) the caudal rib, which arises from the lateral surface of the centrum, and (2) the diapophysis, which springs from the neural arch as in the sacral and presacral vertebræ. These elements are very similar in form to those of the primary sacrals, except that they are connected by a continuous vertical plate which is thickened at its lateral border, forming a stout bar. (Plate LII.)

The *caudal rib* springs from the lateral surface of the centrum, above the middle, in the form of a stout process terminating in an expanded and rugose extremity analogous to the parapophyses. The diapophysial element arises from the lateral surface of the neural arch by anterior, posterior, and inferior roots, analogous to those of the diapophyses in the thoracic vertebræ. The two elements are connected by a vertical plate, which bears on its lateral margin a thickened and rugose surface facing laterally. Passing backward in the series the diapophysial element is reduced to a roughened, vertical ridge on the centrum in caudal IV. The parapophysial element persists as a stout, vertically compressed process as far back as IX, disappearing entirely with XII.

The *centrum* in the first caudal vertebra, as before described, is concave in its upper half, but convex below. The posterior face is irregularly convex. The interior of the centrum has numerous small cavities, especially at the rim of the articular ends. There are no well developed lateral fossæ. With the second vertebra the typical procœlous form of centrum begins. The anterior concavity continues quite marked as far back in the series as the ninth; from this point it diminishes in prominence, disappearing entirely with the sixteenth. The posterior surface of the centrum is but slightly convex in any of the caudal vertebræ. In the second caudal the surface is in general convex with a slight concavity a short distance above the center. Passing backward in the series this concavity increases in area to the obliteration of the general convexity, so that in the seventh the former predominates. From this point backward the posterior concavity persists, being most prominent from the tenth to the sixteenth. From this it will be seen that the procœlous type prevails from the first to the ninth and grades into an uncertain amphicœlous type which prevails as far back as the sixteenth, where it in turn gives place to an irregular amphiplatyan form.

Two sets of *cavities* occur in the centra of the anterior caudal vertebræ, the first above and the second below the root of the sacral ribs. These will be designated respectively as supra- and infra-costal fossæ, according as they occur above or below the root of the caudal rib. These cavities cannot be regarded as constant characteristics, as they are sometimes present on one side and absent on the other. The lateral cavities in the centra persist as far back as caudal V in this specimen. In caudal I the supra-costal cavity is represented by a slight infolding of the periphery of the centrum on the anterior side of the lateral plate. In caudal II cavities are present on both the anterior and the posterior side of the lateral plate. In III there is a single supra-costal cavity on the posterior side; in IV the same persists, but is reduced is size, disappearing entirely with v. The infra-costal fossæ begin with II, become most pronounced in IV, and disappear with v.

The *neural arch* is low and massive throughout the caudal series, the neural canal forming a median groove in the upper side of the centra. The pedicles in the first caudal vertebræ, in addition to being hollow, are excavated laterally by deep cavities, which enter them on the anterior side of the lateral plate. They give rise also to the thin, vertical plate which connects the diapophyses and the caudal ribs. In the second caudal one pedicle is hollow, the other solid. Caudals II to V, inclusive, have the pedicles excavated at the base posterior to the lateral plate. From this point backward the neural arch becomes a simple, low, massive structure, giving rise to the zygapophyses and the neural spines.

The *neural spines* are similar in their elementary structure to those of the posterior dorsal vertebræ. They are composed primarily of a stout median plate and a pair of slighter flanking plates. The median plate is rugose on the anterior and posterior margins for the attachment of inter-spinous ligaments. Near the crest the lateral plates are also thickened and rugose for muscular attachment. In the anterior members of the series the crest is cruciate in cross-section. Two pairs of lateral buttresses which arise from the pre- and postzygapophyses and join the lateral plate, act as a set of brace-roots in resisting antero-posterior strains. These lateral buttresses become rapidly reduced as we pass backward in the series, and disappear entirely in XII. In the first caudal vertebra the spine is similar in height to that of the last sacral, and stands almost vertical, but the spines of the succeeding vertebræ are rapidly reduced in length and inclined backward (Plate LII). In XIV the spine is reduced to a short, blunt median plate and is but little expanded distally. With XVIII the spines begin to elongate antero-posteriorly.

The *zygapophyses* are small in comparison with the size of the vertebræ. They articulate in this specimen as far back as the twenty-third vertebra. The prezygapophyses are borne upon a pair of buttresses, which spring from the anterior surface of the neural arch. In the anterior members of the series they are supported, in addition, by two pairs of posterior roots, which arise respectively from the base of the lateral spinous plate and from the diapophysis, as in the thoracic vertebræ. With the reduction of the diapophysial element in the lateral plate, the third root of the prezygapophysis merges into the first; the second root also disappears in caudal X, leaving only the inferior buttress. The articulating surfaces are convex, and throughout the greater part of the series are directly opposing. However, in the first vertebræ they face upward as well as inward and have their bases excavated by deep lateral cavities. The post-zygapophyses take the form of vertical plates borne upon the posterior angles of the neural spine. They are supported from above by a vertical continuation of the lateral spinous plate. In the anterior caudals there is also a lateral brace which springs from the diapophysial element of the lateral plate.

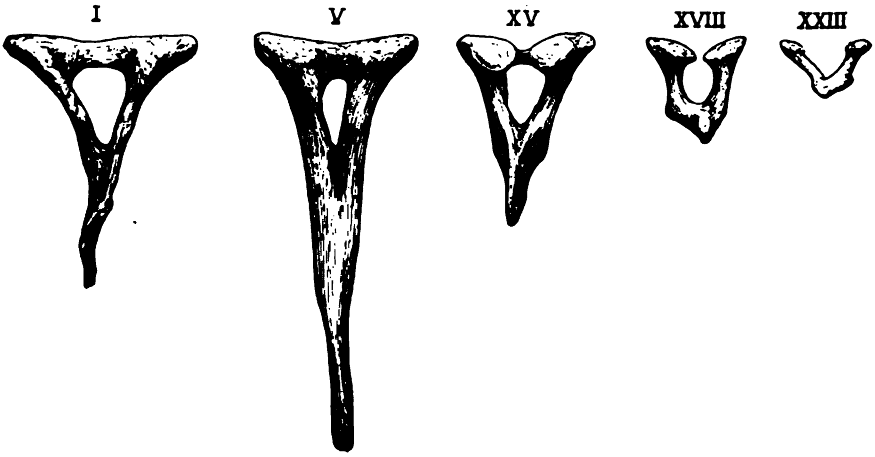


FIG. 18. Anterior view of chevrons, showing gradation in structure.

The *caudal chevrons* are of three types, the closed arch, the open arch, or transitional type, and the double arch. (Fig. 18.) Of these the latter two appear far back in the series where the vertebræ are much reduced in size. The closed arch may therefore be considered as the most characteristic type. Many of the chevrons found with this specimen were so displaced that their position cannot be accurately determined. The presence of a short, stout chevron imbedded in the matrix beneath the first caudal vertebra suggests that all of the anterior caudal vertebræ may have been chevron-bearing.

MEASUREMENTS OF CAUDAL VERTEBRÆ IN CENTIMETERS.

CAUDAL VERTEBRÆ	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII
Height over all	1.13	1.01	.92	.87	.76	.68	.63	.53	.53	.50	.52	.47	.47	.42	.41	.38	.36	.33	.31	.30	.28	.27	.25
Breadth across transverse processes	.79	.65	.61	.60	.57	.57	.54	.50	.49	.44	.36	.32	--	--	--	--	--	--	--	--	--	--	--
Length over zygapophyses	.29	.25	.27	.26	.27	.28	.26	.27	.27	.27	.25	.26	.26	.29	.29	.26	.28	.29	.29	.27	.26	.25	.22
Centrum.																							
Length of	.19	.22	.23	.23	.22	.21	.20	.20	.20	.20	.19	.20	.20	.21	.22	.22	.22	.22	.22	.23	.22	.22	.21
Transverse diameter of anterior end	.39	.38	.36	.35	.33	.31	.30	.29	.29	.29	.28	.26	.25	.22	.22	.21	.21	.20	.21	.19	.18	.17	.17
Vertical diameter of anterior end	.37	.37	.36	.34	.32	.30	.29	.27	.25	.24	.22	.22	.21	.20	.20	.19	.18	.17	.18	.17	.16	.15	.14
Spine.																							
Height above posterior border of centrum	.76	.65	.58	.52	.44	.39	.36	.29	.29	.27	.26	.21	.22	.20	.17	.16	.14	.13	.11	.10	.10	.10	.09
Antero - posterior diameter of median plate at crest	.10	.10	.10	.10	.09	.09	.09	.09	.09	.09	.09	.10	.10	.11	.12	.12	.12	.12	.14	.14	.14	.13	.15
Chevron.*																							
Length of	--	.25	--	--	.34	--	.38	.36	--	-	.30	--	--	.30	.27	.26	--	.18	.18	.15	.09	.06	.05
Breadth at articular end	--	.17	--	--	.14	--	.14	.15	--	--	.15	--	--	.14	.13	.12	--	.12	.11	.11	.09	.10	.07
Greatest breadth of blade	--	.08	--	--	.09	--	.09	.09	--	--	.08	--	--	.07	.06	.06	--	.10	.11	.13	.17	.17	.15

* Positions in series conjectural.

THE PELVIS.

The pelvic bones are well preserved, except the left ilium, which is waterworn. On account of its absence the pelvis is figured from the right side in Plate L, and the same parts reversed are used in Plate LII. The coössification of the pubis and ischium on the right side establishes beyond question the correct relation between these bones. Their distal ends are more divergent than Marsh's figure indicates. This, with the more forward inclination of the whole pelvis, as evidenced by the downward curvature of the presacral vertebræ, directs the ischium more backward and the pubis somewhat more downward than formerly figured in this genus. In fact, these relations approach very closely to those indicated by Marsh's figure of *Atlantosaurus.*[*]

The *ilium* is one-fourth larger than that figured in Marsh's restoration, and shows the character of the crest which was wanting in that specimen. It articulates mesially with the five coalesced sacral ribs and the corresponding diapophyses. The articulating surface for the ribs is a crescentic projection of the mesial surface just above the acetabulum. The greater and lesser peduncles articulate below with the proximal ends of the pubis and ischium, respectively.

The *pubes* are a pair of massive bones, broad in the proximal half and expanded into irregular, rugose knobs distally. They articulate proximally with the great peduncles of the ilium by broad cartilaginous connections, laterally with the ischia by their thin posterior margins, which extend downward from the acetabulum, and distally with one another by a cartilaginous union at the median line. The articulation with the ischia may in advanced age give place to coössification, as has occurred in the right side of the pelvis under consideration. Anterior to the ischio-pubic articulation there is a rugose thickening of the pubic border evidently for union with its fellow at the median line. It is probable that the pubes were connected by cartilage from the ischio-pubic articulation to the distal end. The pubic foramen opens downward just below the anterior border of the acetabulum. (Plate L.)

The *ischia* are much slenderer than the pubes. Their proximal ends are expanded into broad, articular surfaces, which connect superiorly with the lesser peduncles of the ilia, and inferiorly with the pubes by the anterior margin of the blades. They form the postero-inferior boundary of the acetabulum. The shaft curves outward and backward terminating in a rugose knob. From the middle of the shaft to the distal end the pubes are joined in a more or less mobile ligamentary union.

---

[*] Dinosaurs of North America, Pl. XVI.

The *acetabulum* is formed, in its upper half, by the inferior border, and the greater and lesser peduncles of the ilium; in the lower half by the proximal ends of the pubis and ischium. In the normal quadripedal posture the thrust of the femur is received by the inferior border of the ilium just below the sacricostal yoke. In the bipedal posture the weight would be borne by the great peduncle which is supported by the rib of the dorso-sacral vertebra.

The *ribs* of the dorso-sacral vertebra articulate with the anterior surface of the greater peduncle. Similarly the ribs of the caudo-sacral vertebra articulate with the postero-internal surface of the lesser peduncle and with the mesial wall of the iliac plate. From the point of articulation of each of the five sacral ribs a transverse plate extends upward along the mesial wall of the iliac plate. These plates in the left side of the Museum specimen, have become firmly conjoined with the sacral ribs and the diapophyses, leaving only a small foramen above the sacricostal bar.

The *femur* in the Museum specimen is compressed in the shaft antero-posteriorly, but is otherwise splendidly preserved. (Plate LI.) It is a stouter bone than that of any other known Opisthocœlian excepting the unusually stout-limbed form designated by the species, *A. amplus*. The head is rugose and rises five centimeters above the great trochanter. The fourth trochanter is marked by a sharp and rugose ridge at the postero internal angle of the shaft, slightly above the middle. The distal end is expanded into heavy condyles, deep antero-posteriorly. The outer one is cleft by a deep, fibular groove.

MEASUREMENTS.

FEMUR:	M
Length	1.830
Breadth, head and great trochanter	.570
Breadth at middle of shaft	.310
Breadth, distal end	.590
Antero-posterior diameter of inner condyle	.410
Inferior border of fourth trochanter to distal end	.880
Length of fourth trochanter	.400
Antero-posterior diameter of head	.300
ILIUM:	
Length over all	1.300
Acetabulum to superior border	.400
Length of great peduncle on anterior surface	.410
Base of great peduncle to anterior margin	.410
Breadth from lesser peduncle to postero-superior surface	.430
Breadth of acetabulum	515

	M
ISCHIUM:	
Length over all	1.170
Breadth of proximal end	.770
Breadth of distal end	.350
Least breadth of shaft	.170
PUBIS:	
Length over all	1.210
Greatest breadth at proximal end	.860
Greatest breadth at distal end	.480
Least breadth of shaft	.270

RESTORATION.

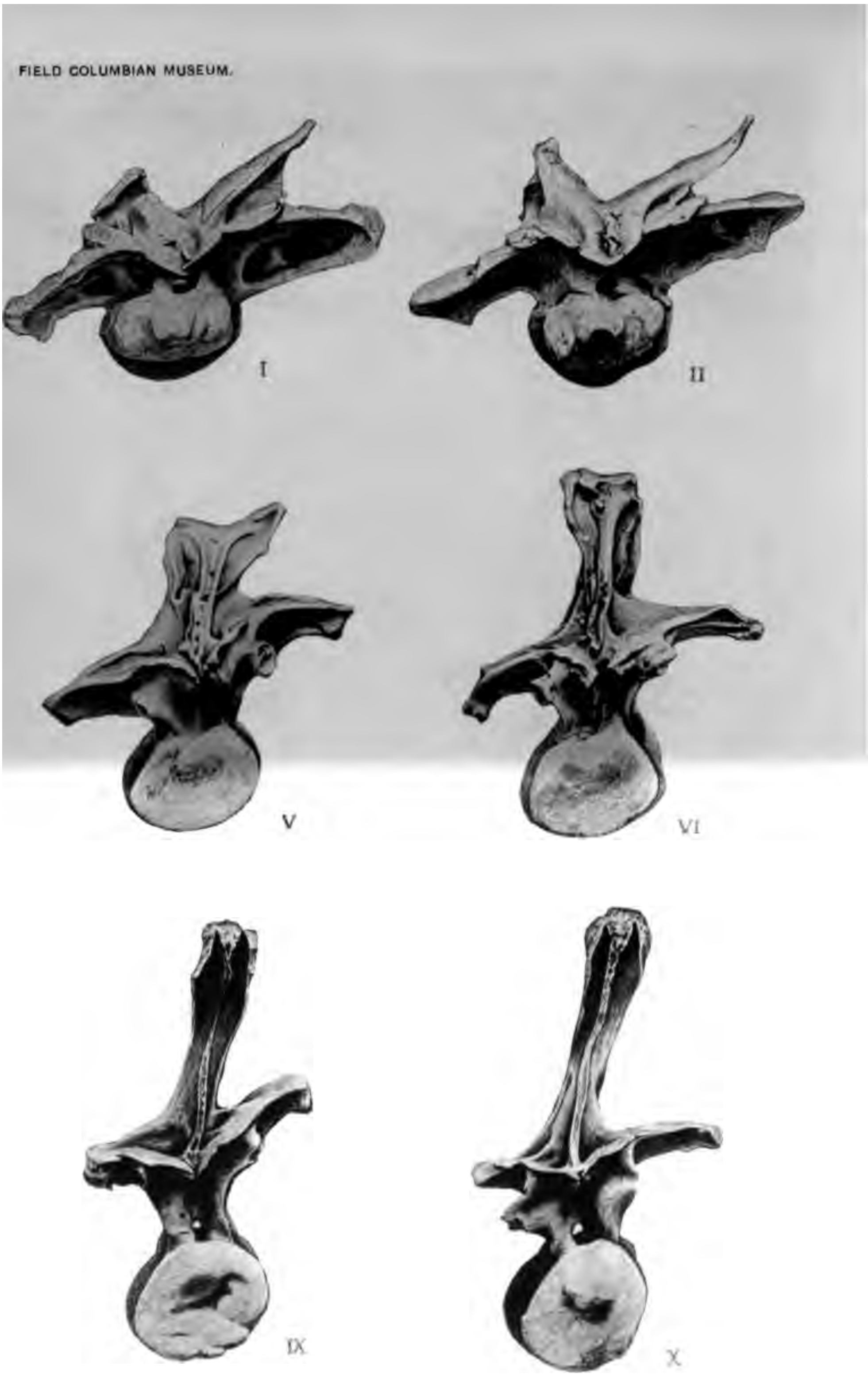
The accompanying figure of the skeleton of *Apatosaurus* (Plate LIII) is based upon the Museum specimen as figured in Plate LII. The cervical series and the limbs are supplied according to Marsh's figure, with certain modifications where it is known to be in error. As the complete cervical series is not known, the number of vertebræ and the character of the neural processes are more or less conjectural. The skull is regarded as essentially unknown. The figure of the Museum specimen is made with the greatest care from projection drawings of each bone made separately and assembled in the figure as a whole. The distortions not corrected in working out the specimen are copied exactly in the drawing. Supplied parts are indicated by dotted lines in the separate figures.

The most noticeable feature brought out is the shortness of the body as compared with other proportions. The crest of the dorsal arch stands just in front of the sacrum. The long spines in this region evidently served as the center-pole to which the muscles for lifting both the anterior part of the body and the tail were attached. In general outline a striking similarity will be noticed between this figure and Marsh's first restoration of this genus. In fact, as pointed out in an earlier note, the original restoration represented almost the entire skeleton and was, in the main, correct. Later, Professor Marsh evidently became dissatisfied with its proportions and inserted three additional posterior dorsal vertebræ, a lumbar, and two cervicals. The number of ribs was raised from ten to thirteen, the crest of the dorsal arch was carried forward to the middle, and a sufficient length of costal cartilage was inserted to extend the thorax in proportion. These additions mark almost exactly the extent of his error.

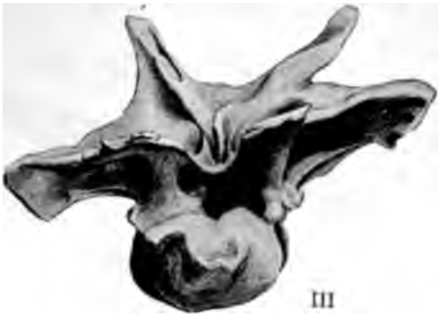
SUMMARY.

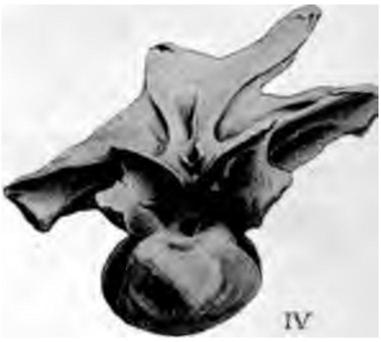
The following conclusions are derived from this paper.

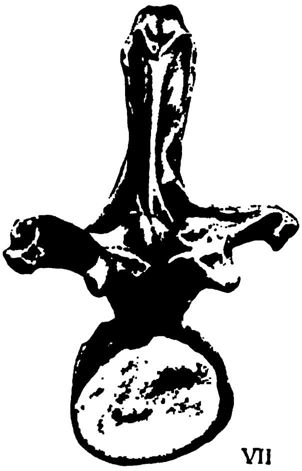
1. "Opisthocœlia" has precedence over "Sauropoda" and "Cetiosauria."
2. *Brontosaurus* is a synonym of *Apatosaurus*.
3. The species *A. ajax* cannot be recognized in the adult; *A. excelsus* is probably a synonym of *A. laticollis*; *A. amplus* is valid.
4. The number of dorsal vertebræ is ten.
5. There are no lumbar vertebræ.
6. There are five pairs of true, and five pairs of floating ribs.
7. The sacrum is made up of three primary and two secondary sacral vertebræ, all of which, in the adult, connect with the ilia by sacral ribs and diapophyses. The primary sacrals are coössified by their centra, zygapophyses, and spines; the secondary sacrals are free until adult age and then coössify with the true sacrals by centra and zygapophyses.
8. Sacral I is a modified dorsal, sacral V a modified caudal.
9. The last pair of floating ribs tends to coössify with the vertebra by head and tubercle, and with the ilia by the distal ends.
10. There are one or two more anterior caudal vertebræ than was figured in Marsh's restoration.
11. The caudal chevrons pass from the closed Y anteriorly to the double-arch type posteriorly very much as in *Diplodocus*.
12. The ilium inclines more forward, and the pubis and ischium are more divergent distally than previously figured.
13. The crest of the dorsal arch is at the anterior end of the sacrum.

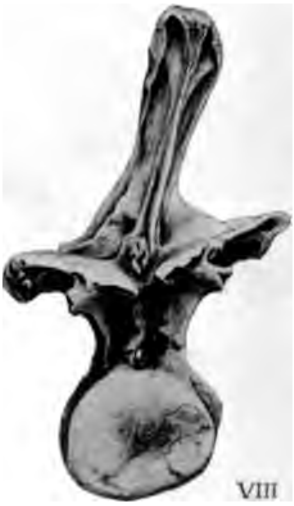


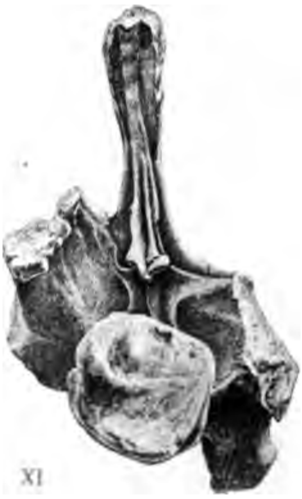
FIGS. I to X. Dorsal vertebræ of Apatosaurus, anterior view, × $\frac{1}{20}$.


III


IV


VII


VIII


XI

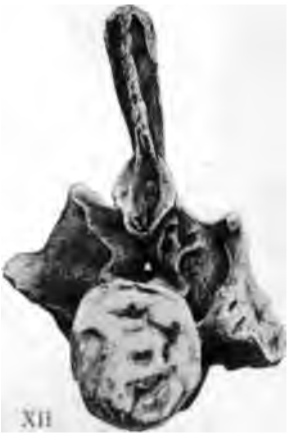
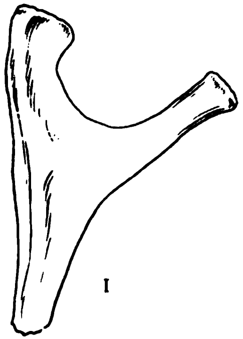

XII

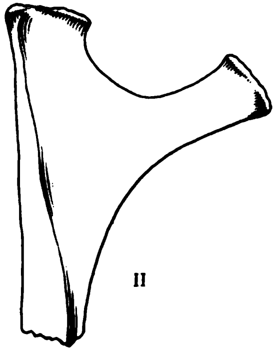
FIG. XI. Posterior view of sacral V. FIG. XII. Same of caudal I. All × $\frac{1}{10}$.

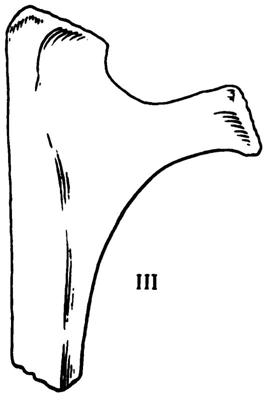
PLATE XLVII.

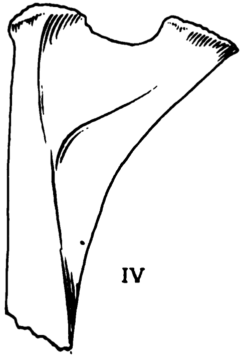
APATOSAURUS.

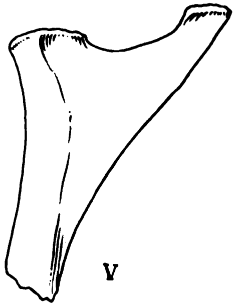
Heads of right thoracic ribs, anterior view, about one-thirteenth natural size.

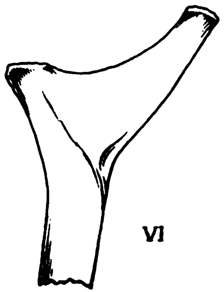

I

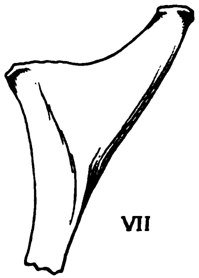

II

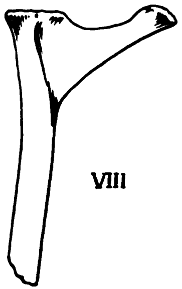

III

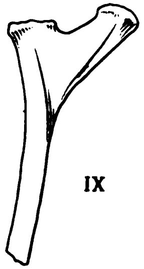

IV


V


VI


VII


VIII


IX

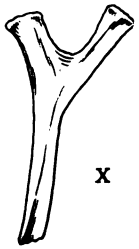

X

PLATE XLVIII.

APATOSAURUS.

Left side view of sacrum, from a photograph, × $\frac{1}{11}$.

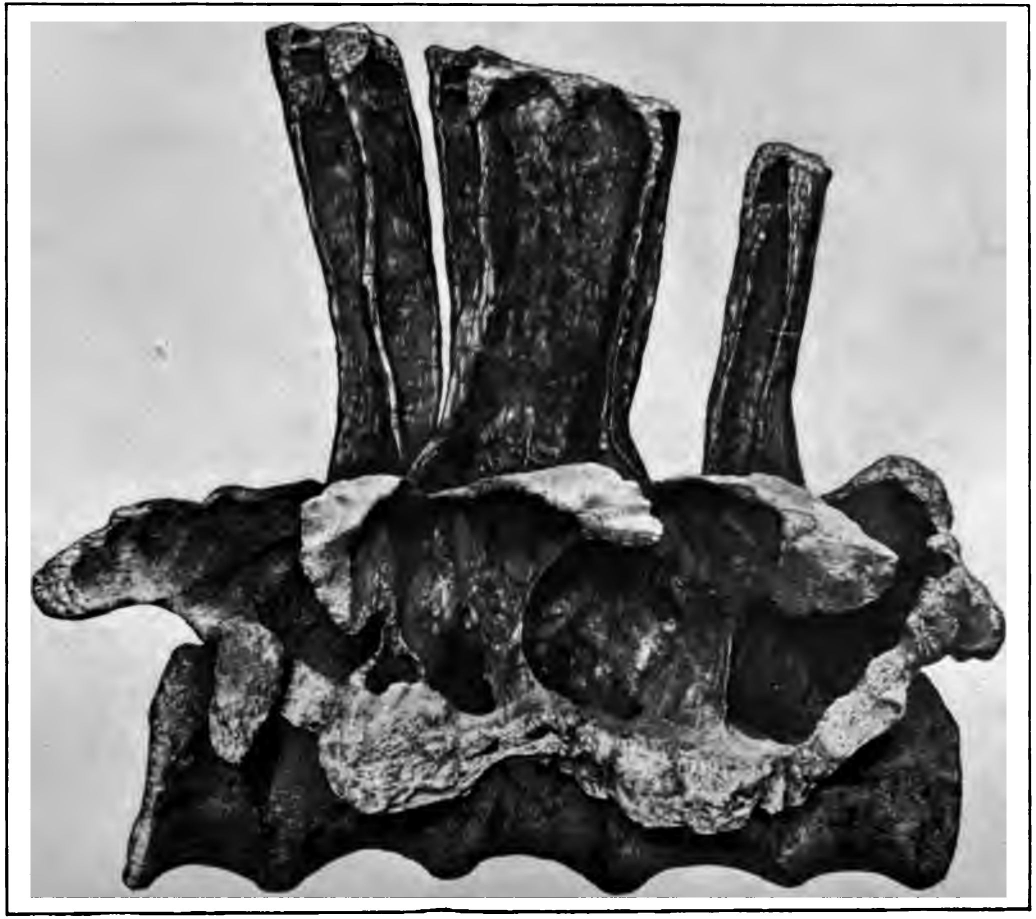


PLATE XLVIII.

APATOSAURUS.

Left side view of sacrum, from a photograph, × $\frac{1}{11}$.

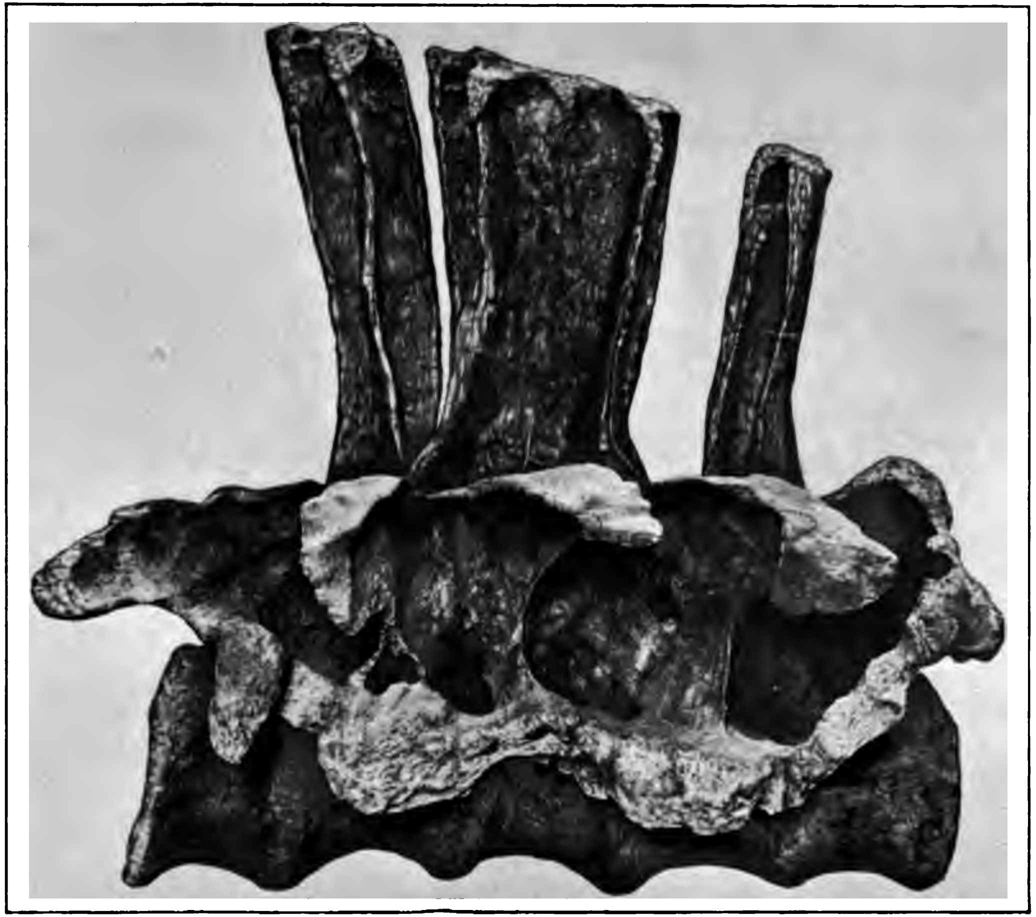


PLATE XLIX.

FIG. 1. Anterior end, sacrum of *Apatosaurus*, × 1/12.
FIG. 2. Anterior end, sacrum of young *Morosaurus*, × 1/8.

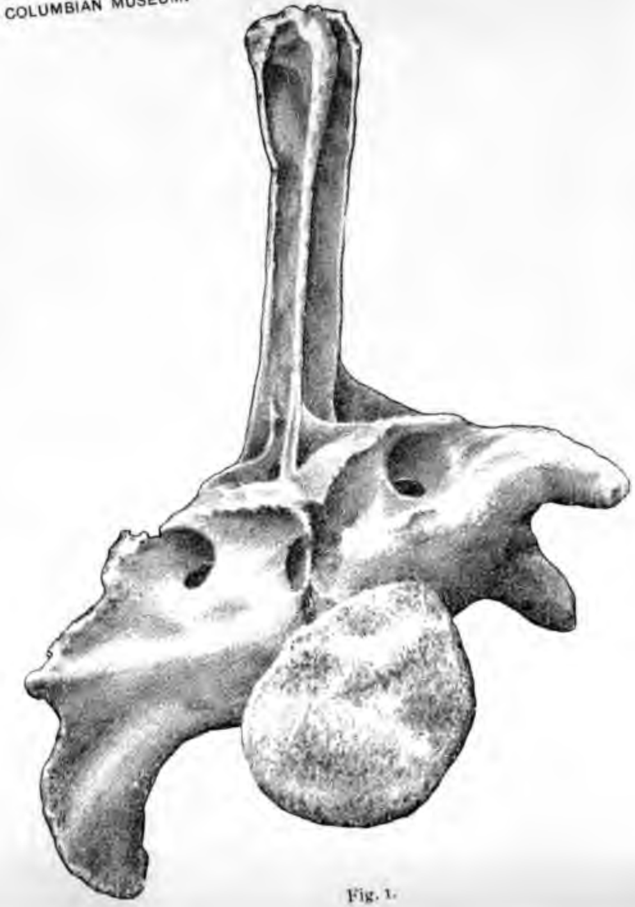


Fig. 1.

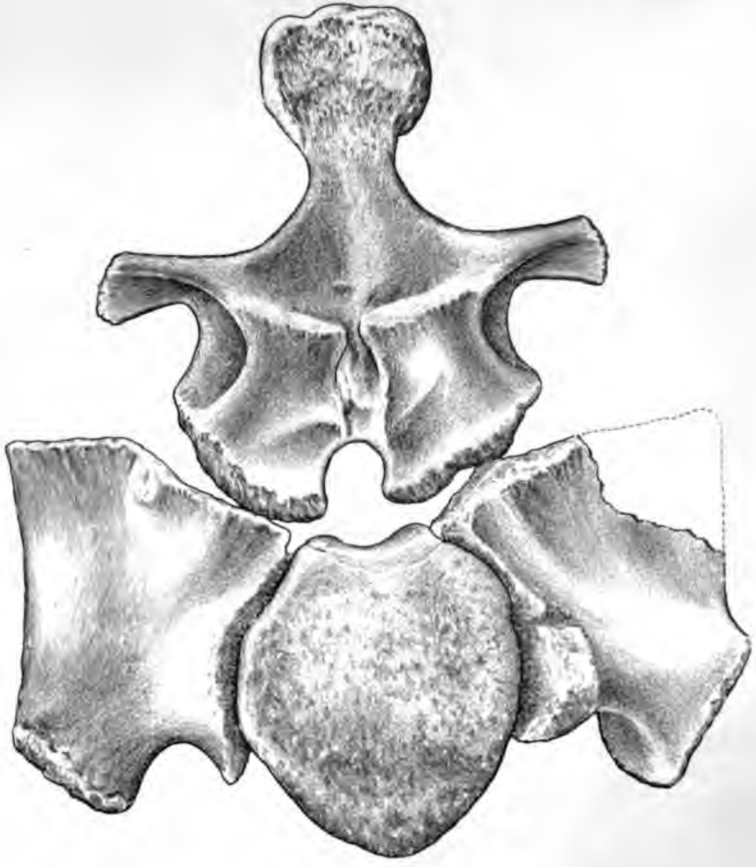


Fig. 2.

PLATE L.

APATOSAURUS.

Sacrum and pelvis from right side, × $\frac{1}{16}$.

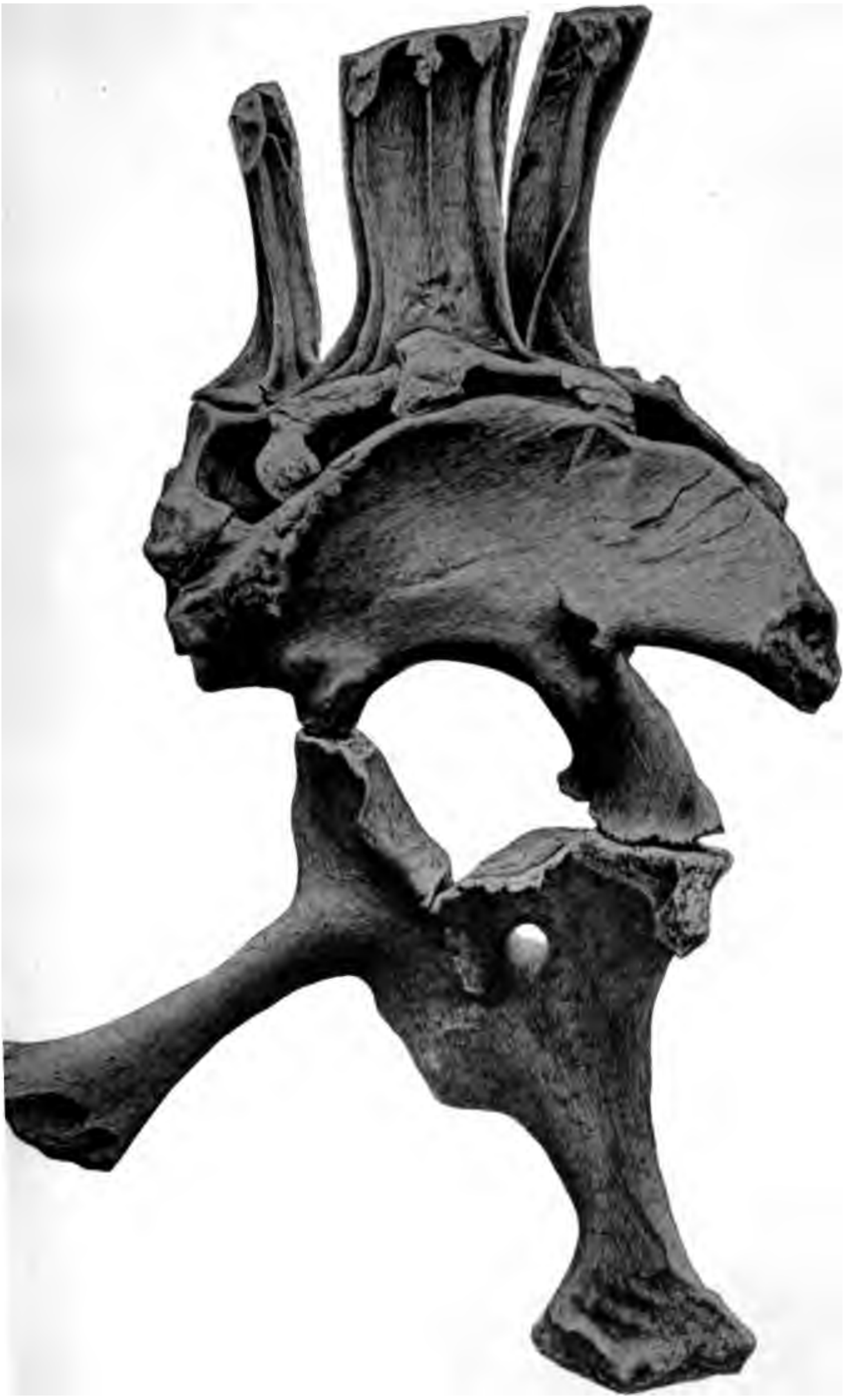


PLATE LI.

APATOSAURUS.

FIG. 1. Lateral view of right femur, × $\frac{1}{13}$.
FIG. 2. Anterior view of same

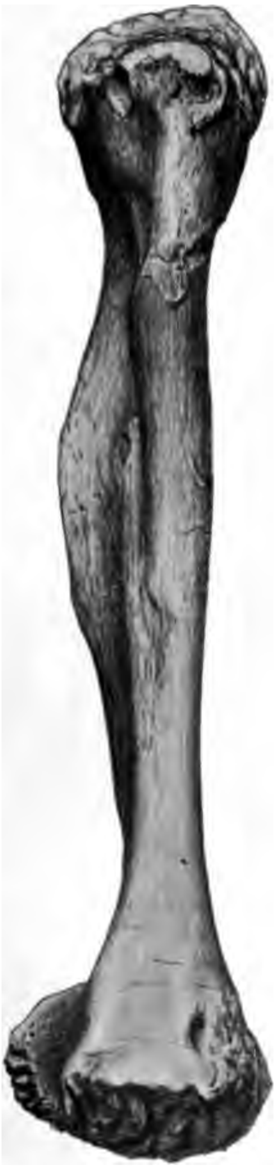


FIG. 1.

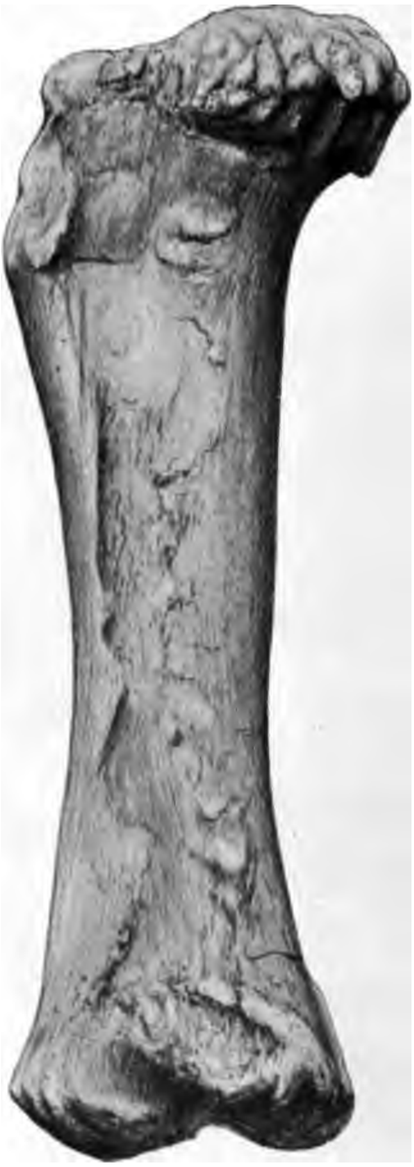
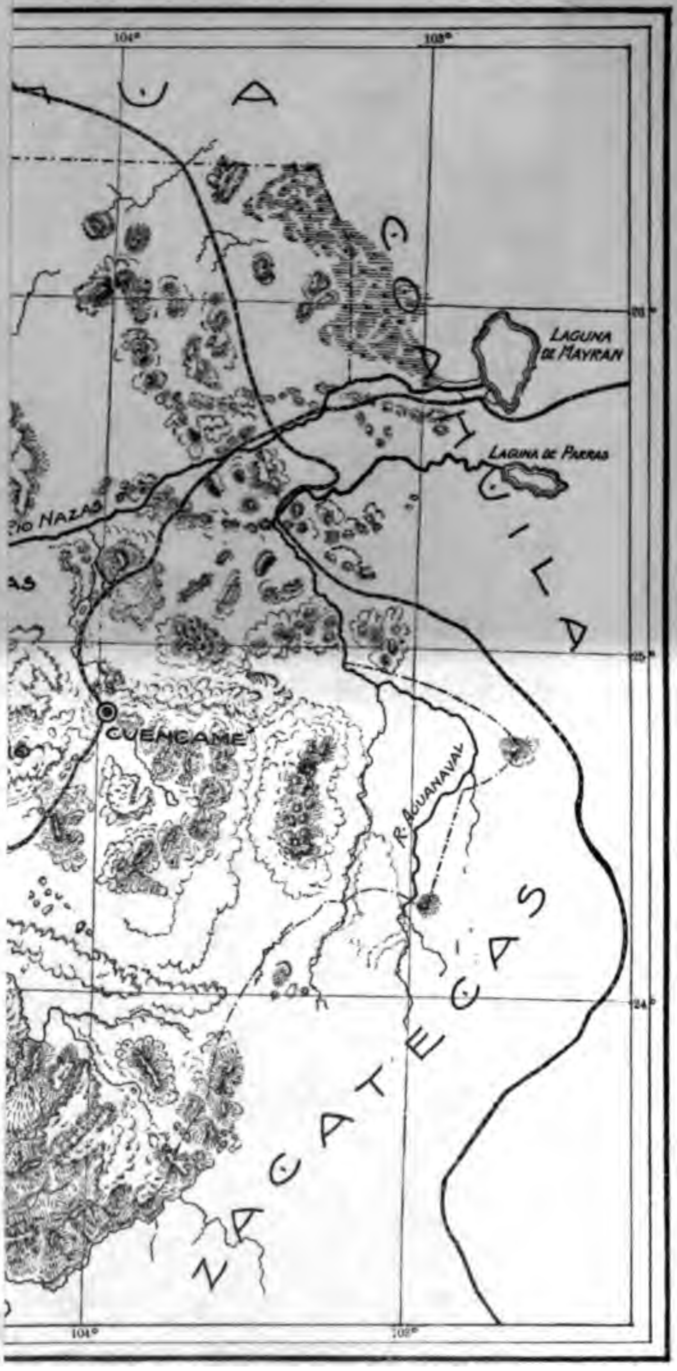


FIG. 2.

GEOLOGY, VOL. II., PLATE LIV.



SCALE, 1 INCH=41 MILES.

IEXICO.

FIELD COLUMBIAN MUSEUM
PUBLICATION NO. 89.
GEOLOGICAL SERIES. VOL. II, NO. 5.

OBSERVATIONS
ON THE
GEOLOGY AND GEOGRAPHY OF WESTERN MEXICO
INCLUDING AN ACCOUNT OF
THE CERRO MERCADO

BY
OLIVER CUMMINGS FARRINGTON, PH. D.
Curator, Department of Geology

CHICAGO, U. S. A.
May 1, 1904.

OBSERVATIONS ON THE GEOGRAPHY AND GEOLOGY OF WESTERN MEXICO, INCLUDING AN ACCOUNT OF THE CERRO MERCADO.

BY O. C. FARRINGTON.

The observations upon which the accompanying paper is based were gathered by the writer during a two weeks' journey in the State of Durango, Mexico, made in the spring of 1896. The journey was so brief that detailed study of the region was not possible. The territory is so little known, however, that even the fragmentary observations that could be made seemed worthy of preservation.

The region especially to be described is that indicated by the route shown on the accompanying map (Plate LIV.), leading from the city of Durango westward to the mining town of Villa Corona, commonly called Ventanas. The distance in a direct line between these two places is about seventy miles, but the circuitous route which must be followed necessitates traveling fully one hundred miles. Travel must be accomplished either on foot or by pack-train. The writer's journey was made both ways by pack-train, which traveled on the outward journey at a rate of about twenty miles per day, while the return was made at a somewhat greater speed. The course followed, for the most part the usual route from Durango to Mazatlan, between which cities a certain amount of traffic is regularly carried on. Numerous mining camps scattered through the intervening mountain region obtain their supplies chiefly from these centers. The territory covered was all comprised within the State of Durango. In a general way the route passed across the western portion of the interior plateau of Mexico, rising gradually from a height of about 6,000 feet at Durango to one of about 9,000 feet, and then a descent was made down the western or Pacific slope to a level of about 2,000 feet.

No previous account in detail regarding the geography or geology of this region has, so far as the writer is aware, ever been published. In a journey from Santiago Papasquiaro southward, Lumholtz touched at San Dimas and Ventanas, and has given a few brief notes regarding general features of the country.*

---

*Unknown Mexico, Vol. I., p. 452.

Weed gives in admirable detail a section about one hundred and fifty miles farther north, his route leading from Parral in Chihuahua via Guadalupe y Calvo to the Gulf of California.* Many of his general observations would apply to the region under discussion.

The City of Durango, at which commenced the present writer's journey over the region especially to be described, is situated upon an alluvial plain hemmed in by low but rugged hills. Eighteen miles to the southeast is a district known as La Breña, which is quite celebrated for its volcanic features. Numerous caverns, extinct craters, crevices full of lava, and heaps of scoria are there said to abound.

The area immediately about Durango is, however, comparatively level. Its climate is semi-arid, and it is therefore treeless. Sufficient grass grows upon the plains, however, to permit of the raising of cattle and sheep on extensive ranches. The soil is fine-grained, and of a yellow color for the most part. About a mile to the north of Durango rises the remarkable Cerro Mercado, or Iron Mountain, a detailed description of which is deferred to a later page. The suburbs of Durango are drained by the Rio Tunal, which joins the Rio Mezquital and empties into the Pacific. The longitudinal valley to the north of Durango, however, is drained by streams which unite from north and south courses to flow eastward. From these streams results the Rio Nazas, which courses lazily through the broad basin known as the Desert or Bolson of Mapimi, until it reaches the Laguna de Mayran. This lake has no outlet. There is little doubt that at one time, however, a stream extended from it to the Rio Grande, two hundred miles to the north, for although the matter has not been studied from the topographic standpoint, a recent investigation of the fish fauna of the Rio Nazas by Meek† shows that Rio Grande species of fish inhabit the Nazas in large numbers. The interruption of the connection may be accounted for in three ways. 1. A warping of the valley. That some warping has occurred is indicated by the basin-like character of the region, also by the existence of lakes in which the rivers terminate, showing drainage from more than one direction. No further evidence in detail regarding crust movements here is, however, at hand. 2. Increasing aridity of climate. That such a change is taking place is commonly believed by residents of the region, who point, in support of their view, to areas now dry which they remember as once covered with water. Hewett is also inclined to favor this view.‡

---

*Trans. Am. Inst. Min. Eng., Vol. XXXII., pp. 444–458.

†Amer. Naturalist, Vol. XXXVII., p. 778.

‡Advance sheet, Discussion of W. H. Weed's Paper, Section Across the Sierra Madre Occidental of Mexico, Trans. Am. Inst. Min. Eng., Vol. XXXIII.

In the absence of detailed and long-continued observations regarding the amount of rainfall, however, such opinions must be accepted with hesitation, since less obvious causes may have produced the results noted. 3. Abstraction of the waters by westward-flowing streams. That to this cause may be chiefly assigned the diminution of the waters to the eastward seems probable. The westward streams are torrential in character, and hence are capable of cutting backward rapidly. Studies by Meek, as yet unpublished, of the fish fauna of the Rio Tunal, show that its fauna is also that of the Rio Grande. Hence the Rio Tunal has probably cut back into streams that once flowed eastward. While no further data on this point are available, it is highly probable that studies of the adjoining rivers would show similar results, and prove that the divide of the Western Sierra Madre as a whole is gradually moving eastward.

Passing westward from Durango, the country appears of a somewhat rolling character, sparsely coated with soil, and semi-arid as to climate. Cacti, mesquite, and scrub oaks constitute the chief natural vegetation. Where the soil is deep, however, corn can be successfully grown. The Rio Chico, here a narrow and easily fordable stream, was crossed some hours after leaving Durango. Its valley is several hundred feet deep, with steep and terraced sides. Three distinct terraces were noted, but of their origin nothing can be stated.

The rocks for a long distance westward were plainly eruptive in character, generally porphyritic, and appearing to be dacites and rhyolites. The topography is characterized by a series of monoclines dipping to the east, with abrupt faces to the west. Thus the plateau rises westward by series of low steps.

The aridity of the country continued until toward the close of the second day's travel, when pines began to appear. These soon thickened into extensive forests such as are shown in Plate LV. During the journey of three following days, this pine forest continued almost without interruption. Variations in the size and height of the trees occurred, and there were occasional rocky areas where trees could not grow, but the general character of the region was forested. Some flat areas were also treeless, on account, probably, of their submergence during the rainy season. The species of pine constituting the forests was, in general, a long-leaved sort. The larger trees were about two feet in diameter at the butt and perhaps fifty to sixty feet high. They rarely exceeded this size, and averaged smaller. As usual in pine forests, there was an entire absence of underbrush.

The trunks of the trees were often blackened by fire, but the trees themselves rarely showed signs of injury from this cause. Oaks were interspersed among the pines, and these grew more abundant toward the west. In the open spaces grass grew abundantly, but deciduous bushes or trees were generally few. Signs of animal life were not abundant. At night the barking of coyotes could be plainly heard, especially as the higher elevations were reached. Hunters from Durango and other cities are accustomed to visit the region to procure deer and mountain lions, but neither were seen on the writer's journey.

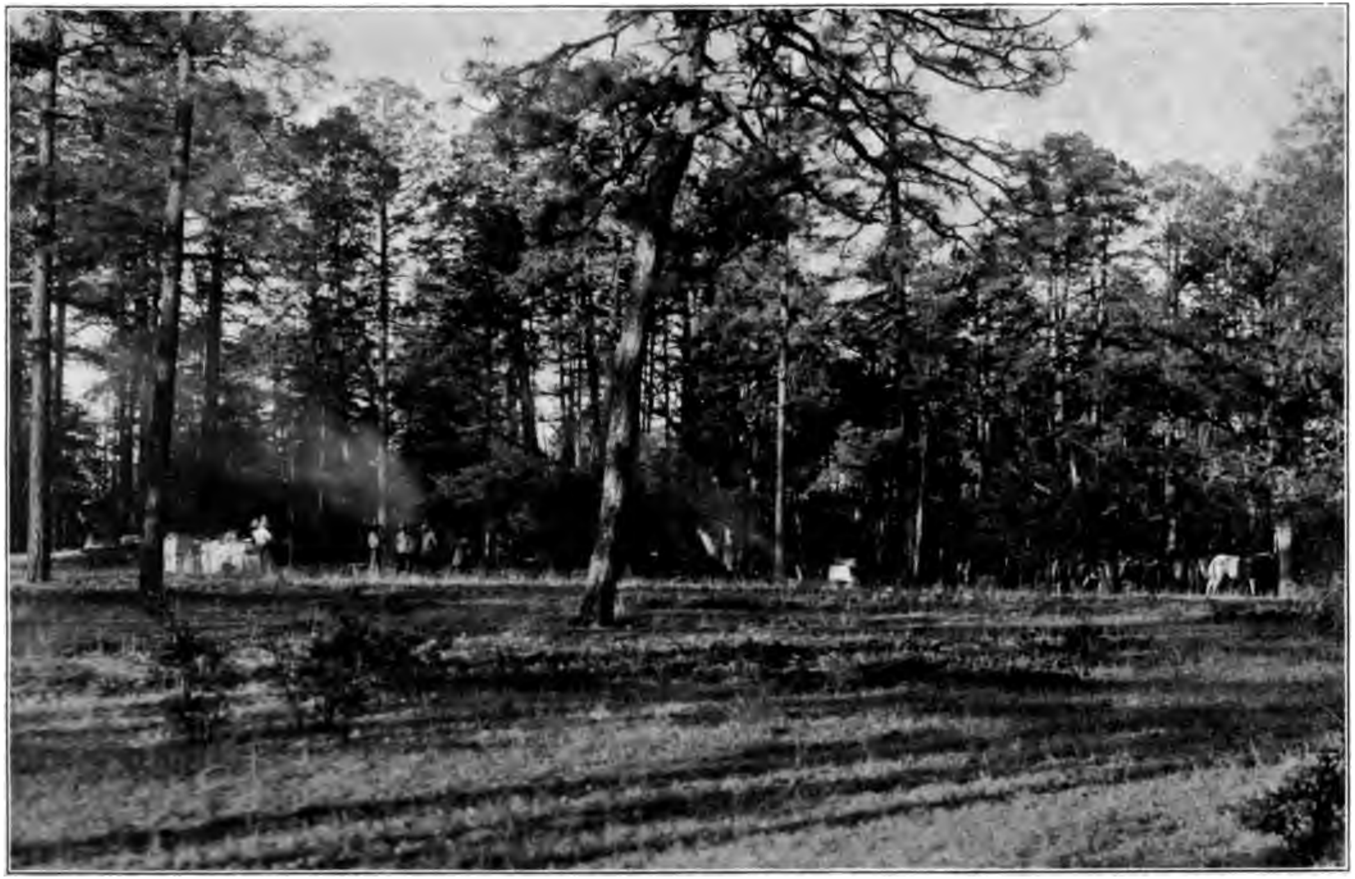
By man the region is practically uninhabited. Three so-called ranches were passed, which employ from three to ten hands each, but their production is scanty, and their income seems to be derived chiefly from the sale of supplies to passing pack-trains. Small herds of cattle belonging to these or other ranches were occasionally encountered, but the possibilities of the region for grazing purposes seemed to be practically unutilized.

Pack-trains, going to Durango chiefly from Mazatlan, were passed at least as often as every day, and sometimes two or three in a day. The trains were usually small, numbering from three to fifty mules, and were laden with tropical fruits, corn, or other staples. Occasionally foot travelers making the same journey were also encountered, their burden being in one case parrots and in another straw "sombreros."

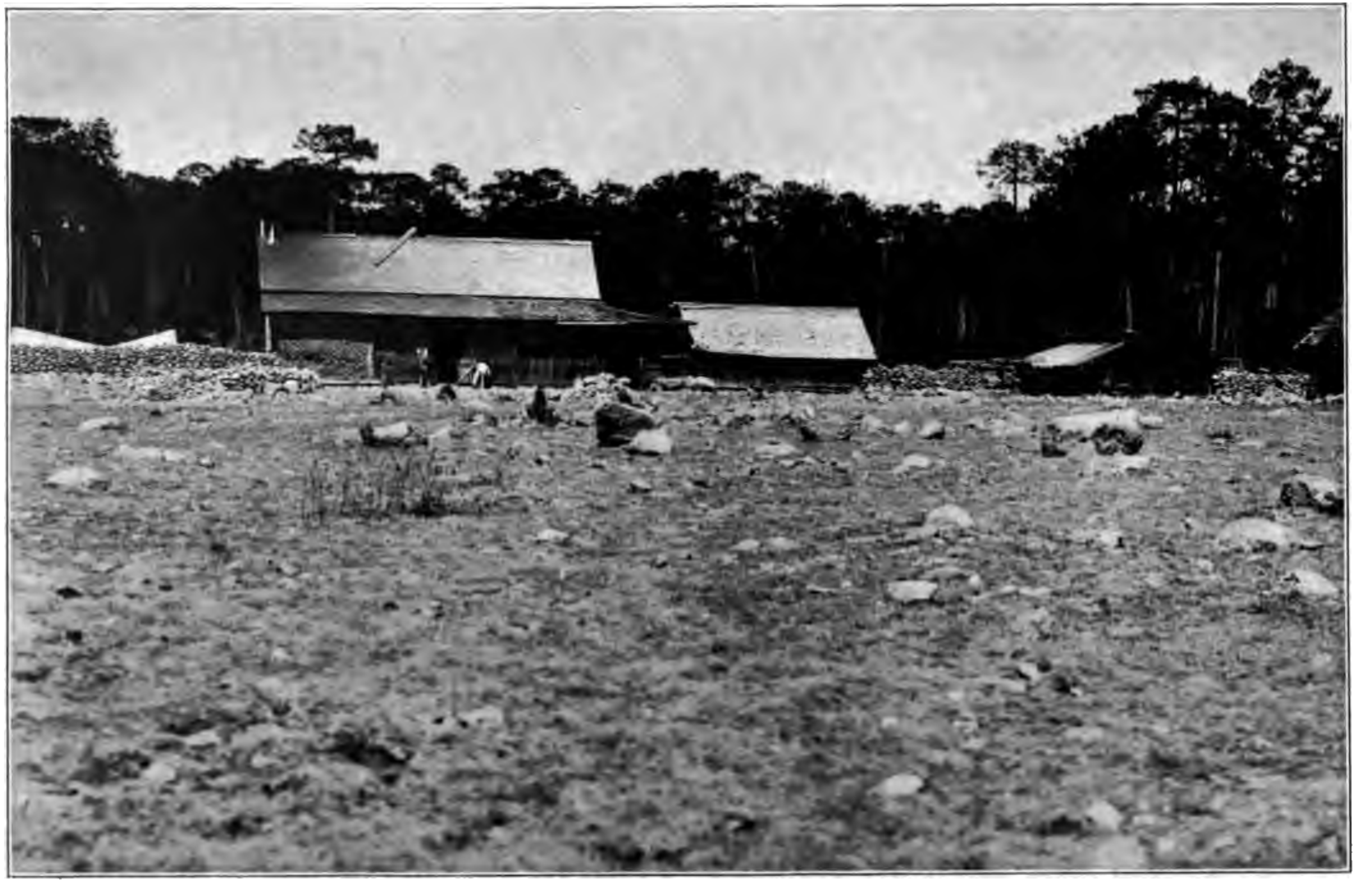
Such rocks as could be observed in passing were plainly of igneous origin, tuffs being prominent among them. Occasionally chalcedonic and jasperized seams were noted, indicating a secondary infiltration of siliceous waters.

The steady upward trend of the plateau was made evident by a change in vegetation and an increasing coolness of temperature. At the higher levels the climate is too cold for even the growing of wheat. Grass suitable for cattle grows in abundance, however, even at the highest part of the plateau. Mountain streams with clear waters were crossed at intervals, giving evidence, together with the abundant forests, that this part of the plateau is well watered.

On the evening of the fifth day a group of rude buildings, known as the Ciudad ranch (Plate LVI.), was reached. This ranch derives its name from the fact that in its vicinity occurs an area of remarkable erosion forms, known locally as La Ciudad de Rocas ("The City of Rocks"). Although the area is not visible from the trail itself, it can be seen by going a short distance from the latter. Mr. Rich, at that time manager of the ranch, kindly guided me to some glimpses



Photograph by the Author.



Photograph by the Author.

Ciudad Ranch, five days west of Durango. This is located at about the highest point of the plateau. The buildings occupy a clearing in a pine forest which covers the plateau in every direction.

of the area, the character of which can be judged from the accompanying views, Plates LVII. and LVIII.

The area is one of erosion forms, the channels between which are worn down to a remarkably uniform level, so that prominences seem to arise thickly over it as from a floor. The height of these prominences is from about thirty feet down. As compared with the erosion forms so common in the bad lands, those of the Ciudad de Rocas merit attention on account of the absence of pinnacles, peaks, ridges, and angular outlines in general. Their outlines are, on the contrary, domed and rounded, and exhibit convex and concave curves. On closer study the difference in outline appears less than at first sight, since, as has been shown by Gilbert,* the profiles of bad land slopes also exhibit convex and concave curves when viewed in a large way. Convex curves upon eroded areas have been shown by Hicks to be due to weathering and concave curves to water sculpture.† The manner of production of the convex or weather curve is thus described by that author: "The weathering of structural blocks reduces their salient angles, which are attacked from both of the adjacent faces at once. At the point *x* (Fig. 1) the disintegrating forces act with twice as great intensity as at *b*, since the attack comes from two directions. The effects are more than twice as great at *x*, because the products of decay are quickly removed, exposing fresh surfaces to the attack, while at *b* they remain to cover and protect the subjacent beds. Thus the structural block *m n o p* is rounded off by weathering. The new outline *a b c* is composite. The portion *d b e* is a weather curve, convex upward. If weathering alone, without the aid of flowing water, has been concerned in the sculpturing process, the talus slopes *a d* and *c c* will be structural planes, not curves. The structural angle *c c p* will be determined by the resting angle

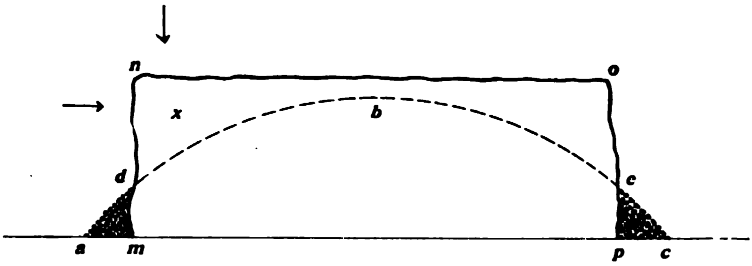


FIG. 1. Weathering of structural block with talus. After Hicks.

---

*Report on the Geology of the Henry Mountains, pp. 122, 123.

†Bull. Geol. Soc. Amer., Vol. 4, pp. 133–146, 1893.

of the materials composing the talus, and that again will depend upon the size and form of the particles; but in humid regions the talus slopes will be quickly molded into water curves. * * * The resulting form *a b c* will be a rounded rock, a smooth knob, or a round-topped hill or mountain, according as the original block was measured by inches or leagues."

While this account may be considered in a general way descriptive of the process which has been foremost in the production of the forms of the Ciudad de Rocas, the manner there has been somewhat different, since there is a notable absence of talus in the area. Not only is there practically no talus on the slopes of the prominences, but it is even lacking on the level floor as well. While a few small trees and bushes find sufficient soil for their growth, the area is practically treeless, although surrounded by a dense forest. Hence the sides and tops of the prominences lack the protection postulated by Hicks, and a somewhat different form is produced. In general, it may be assumed that this form would be somewhat steeper (Fig. 2), since the protective influence of the talus at the sides would be lacking. Nevertheless, the tendency to steepness from this cause would be somewhat counterbalanced by a similar lack of protecting talus at the top, so that the form in any particular case would be the resultant of a large number of forces. The remarkably complete removal of the products of decay from the Ciudad de Rocas indicates probably a relatively slow disintegration of the rock as compared with the speed at which the sandstones and clays of bad land regions break down. This relatively slow disintegration is due partly to the texture and composition of the rock, and partly also probably to a scarcity of joints, thus limiting the number of points of attack. The detritus formed is thus not greater in amount than can be removed by local winds, rains, and rills. Another structural or textural feature indicated by the convex forms is an increasing hardness of

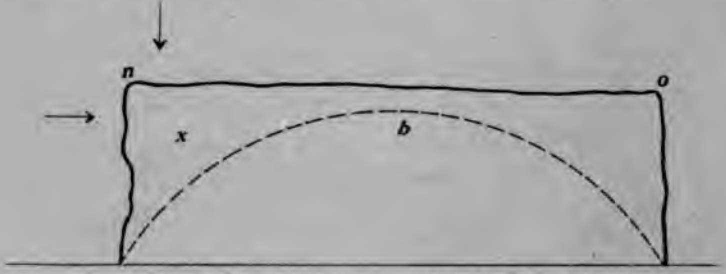
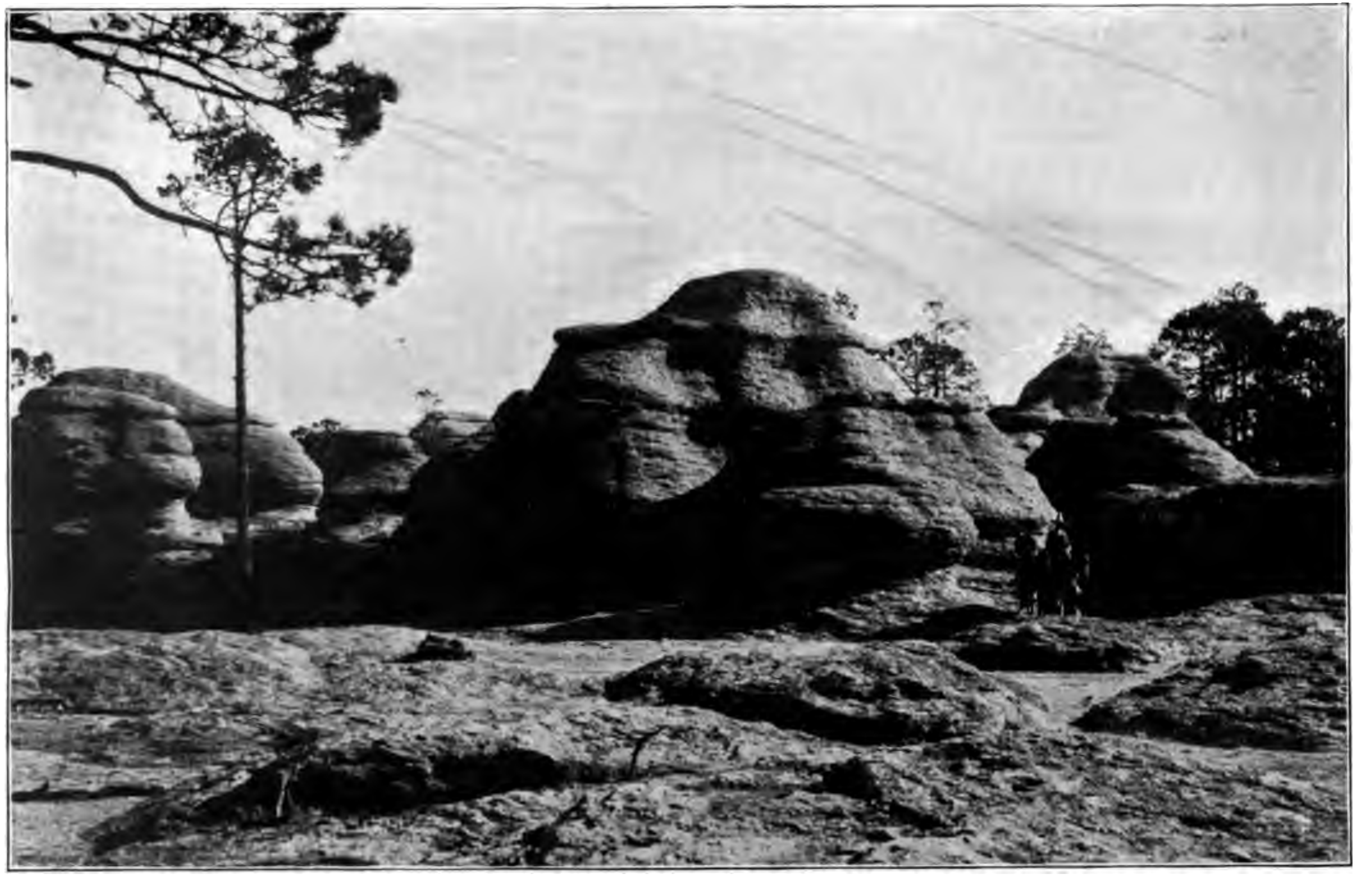


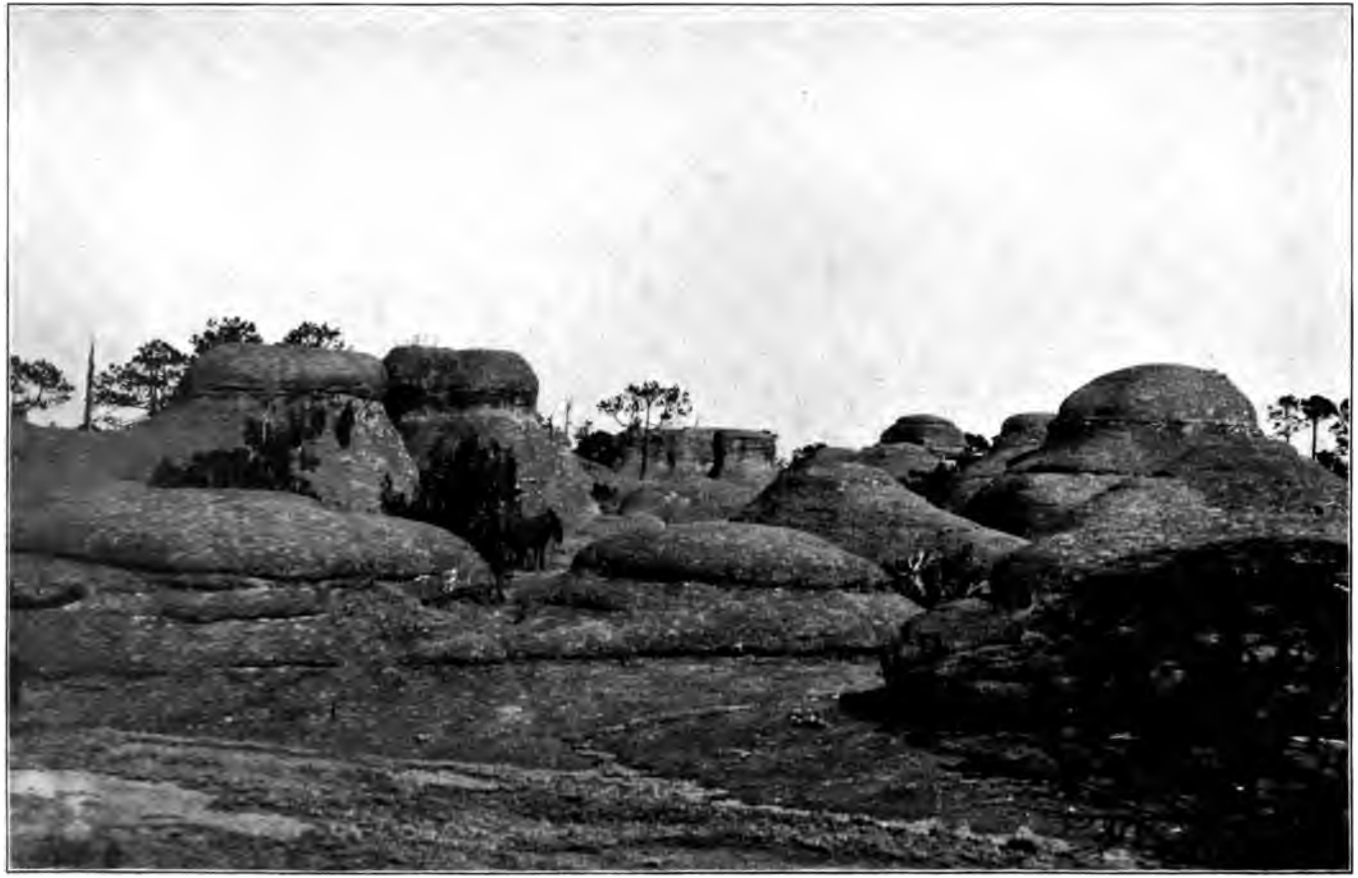
FIG. 2. Weathering of structural block without talus.



"CITY OF ROCKS" (CIUDAD DE ROCAS).

An area of remarkable erosion forms near the Ciudad Ranch.

Photograph by the Author.



View in the "City of Rocks."

Photograph by the Author.

the beds downward, the term hardness being here used in the sense of affording relatively great resistance to weathering. This increase in hardness may characterize the rock itself, or may be due simply to a softening of the upper layers through weathering. There must be few inherently harder layers in the rock, since, if these existed, whenever they came uppermost the portions below would tend to suffer excavation so as to form the pinnacles and pillars characterizing bad land topography. At a few points in the Ciudad de Rocas there may be noted a tendency to the production of such forms. A combination of convex and concave forms is also quite frequent. Generally, however, convex forms predominate. On the whole, the Ciudad de Rocas affords an illustration of the weathering of a relatively homogeneous, rather highly resistant rock, little jointed, and largely free from the influence of talus or detritus of any sort.

Regarding the extent of the area over which the erosion forms are to be seen, the writer could learn nothing definite. The ranch manager, Mr. Rich, was inclined to think from such observations as he had made that the area was a considerably elongated one in outline, and that in the direction of its greatest length, a north and south direction, it probably extended several miles. He had never explored the area to its limits, however, and knew no one who had.

The rock of the area, so far as observed by the writer, was generally homogeneous in character throughout. In color, as seen from a distance, it was gray. In a hand specimen, a general reddish cast is prominent, the color being a pale, dull red flecked with white, and showing violet seams. An indistinct, irregular lamination is visible, produced by alternate layers of red and violet, averaging about one millimeter in thickness. (See Fig. 3.) Occasionally the violet-colored seams are much wider, reaching one centimeter in the thickness, and probably more at times. The arrangement of the red and violet layers is not parallel except in a general way, nor is their width uniform. On the contrary, they branch and run into each other. Besides differing in color, the red and violet layers are unlike in hardness and texture. The red layers are compact, and have almost the hardness of quartz, while the violet layers are more or less pumiceous and friable in character. Cavities a centimeter or more in length and two or three millimeters wide are visible through them, and the general texture is quite open. Doubtless the abundance of these layers through the rock has aided materially in its disintegration. The white flecks, previously mentioned as scattered through the rock, are porphyritically developed feldspar crystals. They are square to rectangular in outline, and in size range from two square millimeters down. They are thickly scattered through both the red and violet layers, but are rather more abundant in the former. Magnetite is also present in minute grains, rarely visible in the mass of the rock with the naked eye, but readily separating with a magnet when the rock is powdered. In thin section the feldspars, with occasional grains of magnetite, form the only individualized minerals. The feldspars show polysynthetic twinning, often with undulatory extinction. They are generally undecomposed and free from inclusions. The alternate arrangement of compact and pumiceous streaks seen with the naked eye appears in greater detail when observed under the microscope. Bands appearing wholly compact megascopically, are seen microscopically to be penetrated with narrow, elongated, pumiceous streaks. The compact bands are heavily impregnated with an opaque red pigment, which is doubtless oxide of iron, that renders them nearly opaque, even in thinnest section. The pumiceous streaks are composed of great quantities of lath-shaped microlites, generally arranged in a confused fashion, though sometimes exhibiting a partly radial arrangement. There is also much curving and twisting of glass fibers and microlites, especially about the phenocrysts. The characters described

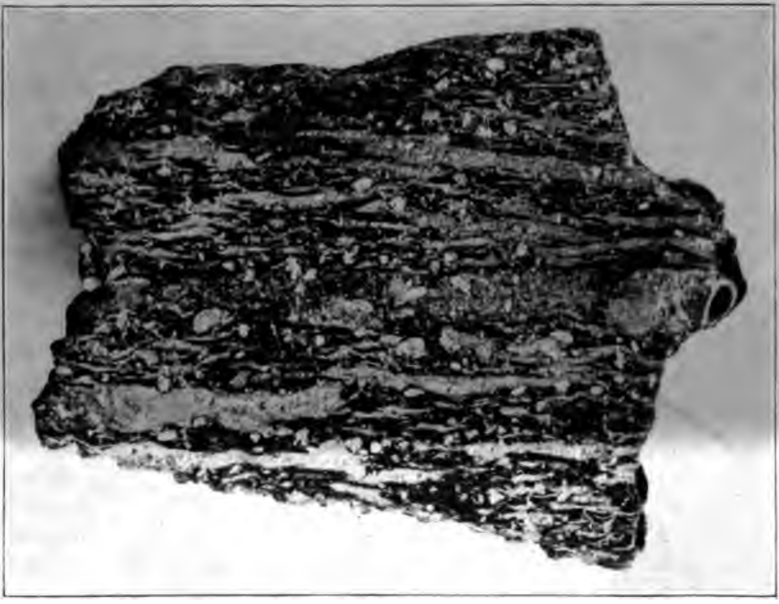


FIG. 3 Rhyolite. Ciudad de Rocas. x 1.

by Iddings as belonging to a collapsed pumice,* are many of them seen here in great perfection, and the structures correspond closely with those shown in the photomicrographs Fig. 3, Plate L., and Figs. 1 and 2, Plate LI. of the same work.

An analysis of a hand specimen of the rock collected by the writer was made by Mr. H. W. Nichols, of the Department of Geology of the Museum. The results were as follows:

Analysis of Rhyolite, Lassenose, Ciudad de Rocas, Mus. No. Li 1829.

$Si\,O_2$	66.77
Al_2O_3	17.40
Fe_2O_3	2.87
$Fe\,O$	0.33
$Mg\,O$	1.05
$Ca\,O$	1.49
Na_2O	5.81
K_2O	2.13
H_2O	1.14
$C\,O_2$	None
$Ti\,O_2$	Trace
P_2O_5	None
$Mn\,O$	0.12
$S\,O_3$	0.87
$Pb\,O$	Trace
Sp. Gr. = 2.417	99.98

Calculation of the mineral composition of this rock from the analysis according to the methods recommended by the authors of the quantitative classification,† would give, if the writer has correctly interpreted them, the composition shown in the first column below. But to the present writer it would seem more reasonable to interpret the excess of alumina as representing kaolinite resulting from the decomposition of the feldspars than to consider it corundum. Since the other components of kaolinite, viz., silica and water, occur in the rock in quantity sufficient to combine with the alumina, assumption of the presence of kaolinite seems justifiable. Accordingly, the second column shows the composition of the rock if the presence of kaolinite is assumed, the further assumption being made that it is formed by the alteration of the plagioclases, since, as is well known, these break down before the orthoclase. If kaolinite be present, however, it represents original feldspars, and a simple calculation serves to determine the original quantity of these in the unaltered rock. The result of this calculation is given in the third column below, and more nearly represents, in the view of the writer, the mineral composition of the rock than that of the first column.

---

*Monograph U. S. Geol. Survey, Vol. XXXII., Pt. II., pp. 404–406.

†Quantitative Classification of Igneous Rocks, Cross, Iddings, Pirsson, and Washington, 1903, pp. 187–209.

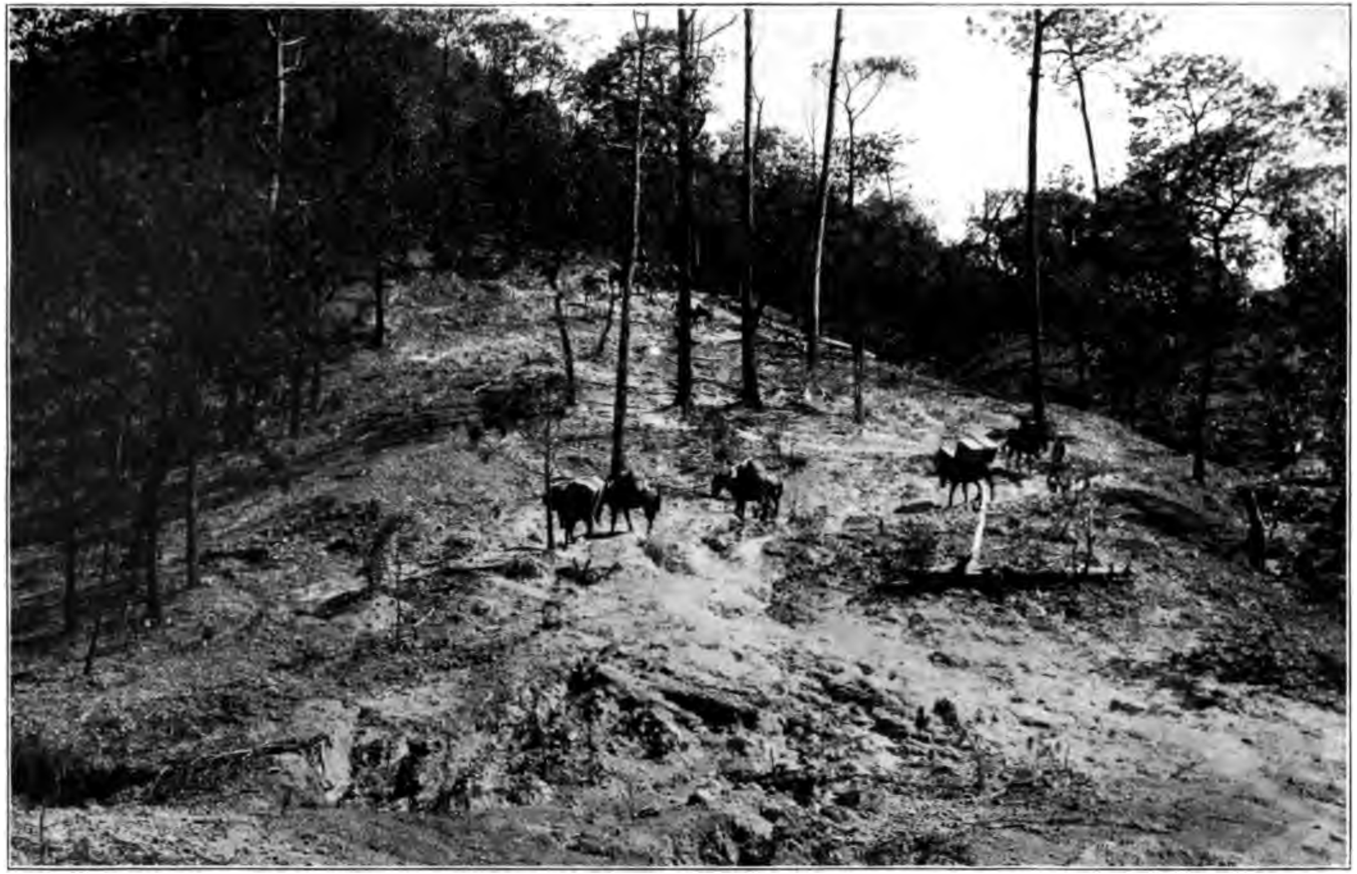
	Quantitative composition.	Composition as affected by kaolinite and limonite.	Composition of unaltered rock.
Quartz	19.92	16.58	11.39
Orthoclase	12.23	12.23	12.23
Albite	49.26	49.26	60.60
Anorthite	7.51	7.51	9.25
Corundum	2.86	.....	.....
Kaolinite	....	7.20	.....
Hypersthene	3.26	3.26	3.26
Hematite	2.87	2.04	2.87
Limonite	....	0.97	.....
Water	1.14	.....	.....
SO_3	0.87	0.87	0.87
	99.92	99.92	100.47

From the composition given in the first column, the classification would be Class 1, Persalane, Order 4, Brittanare, Rang 2, Domalkalic, and Subrang 4, Dosodic, Lassenose.

The composition as given in the third column would change the position of the rock in classification slightly, putting it in Order 5, Canadare, and making it Laurvikose.

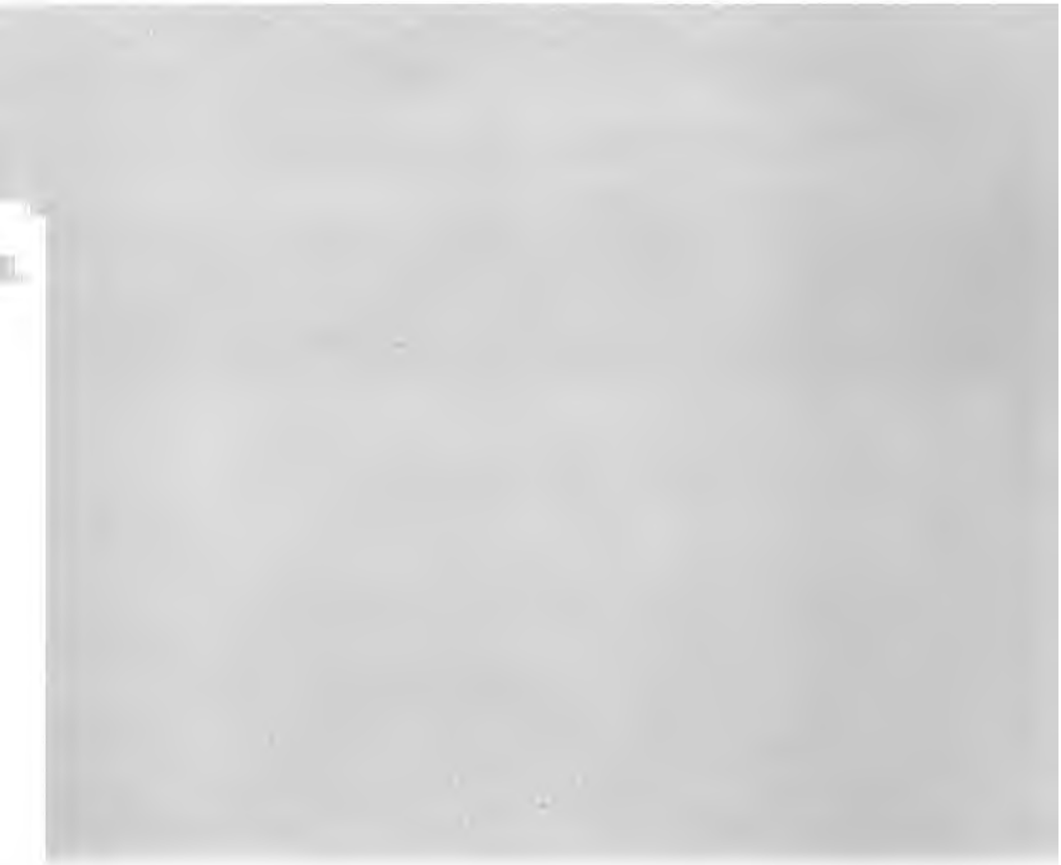
About two hours from the Ciudad de Rocas, at one point on the trail, a considerable quantity of black obsidian in the form of scattered fragments was seen. The fragments were observed over an area several rods in extent, but no outcrop of the rock in place was visible in the immediate vicinity. The fragments ranged in size from pieces as large as one's fist downward. They were generally more or less rounded, but showed no evidence of artificial flaking. As the number of known occurrences of obsidian in Mexico is very few, this one is of interest to add to the list, and it is also of importance as illustrating the igneous nature of the rocks which cap the surface of the plateau.

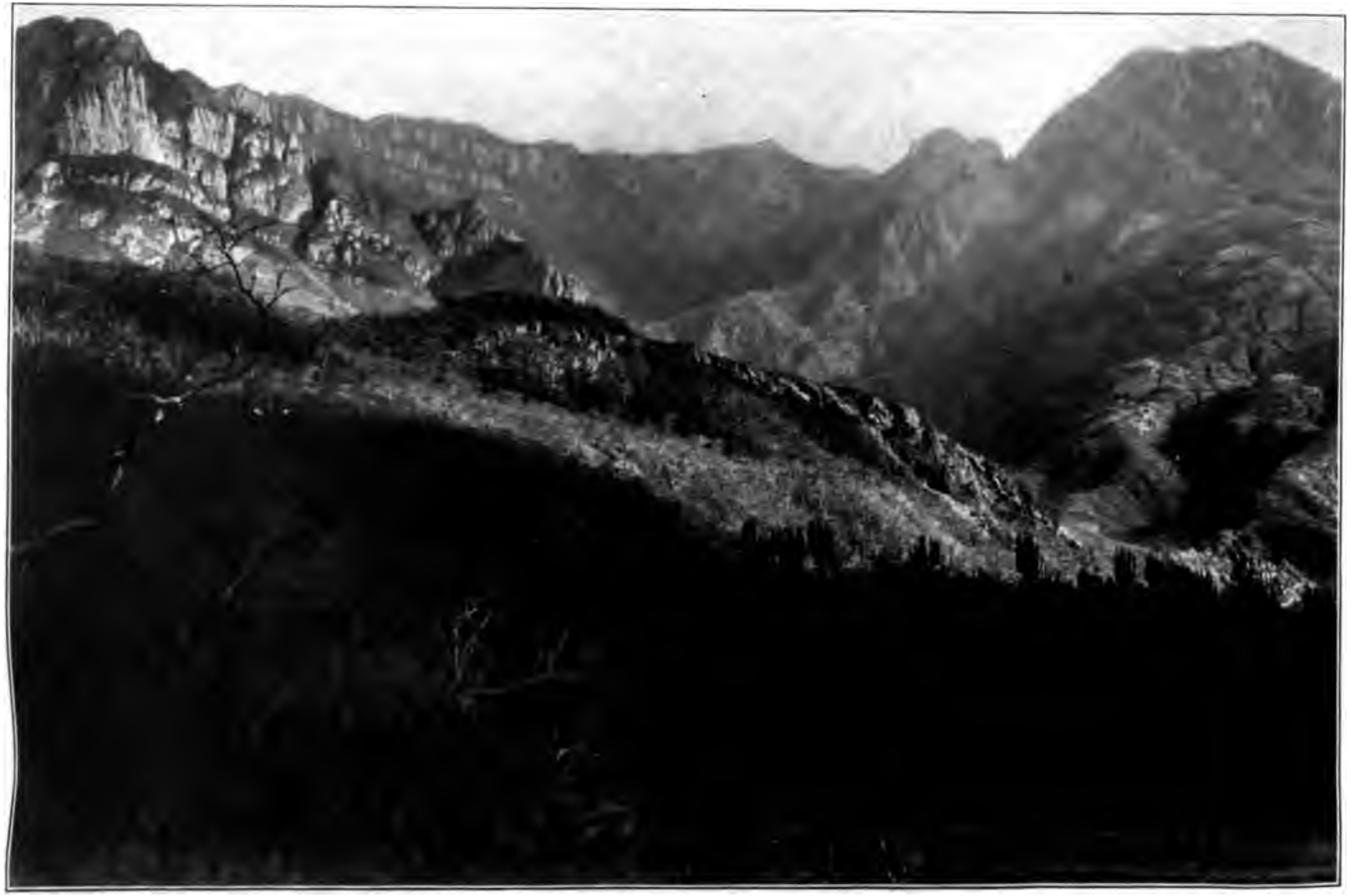
A few hours west of the Ciudad ranch the way began to descend, and soon the western edge of the plateau was reached, where the mountains of the Pacific slope came into full view. As far as the eye could sweep, north, south, and west, a maze of peaks and valleys appeared, forming a veritable sea of mountains. (Plates LXI., LXII., and LXIII.) The summits of these did not appear to be elevated above the plateau, but to reach approximately to its level. They evidently originated from a profound dissection of the edge of the plateau by swift, short rivers, since they tend to run in ridges transverse to its border. The peaks in form are sharp and angular, and they are separated by deep, steep-walled valleys. Bold cliffs are common, and the waste slopes are steep and largely barren of vegetation. The valleys nearest the plateau often have a well-marked amphitheatre-like form, as illustrated by the one shown in Plate LX., and a general



Photograph by the Author.

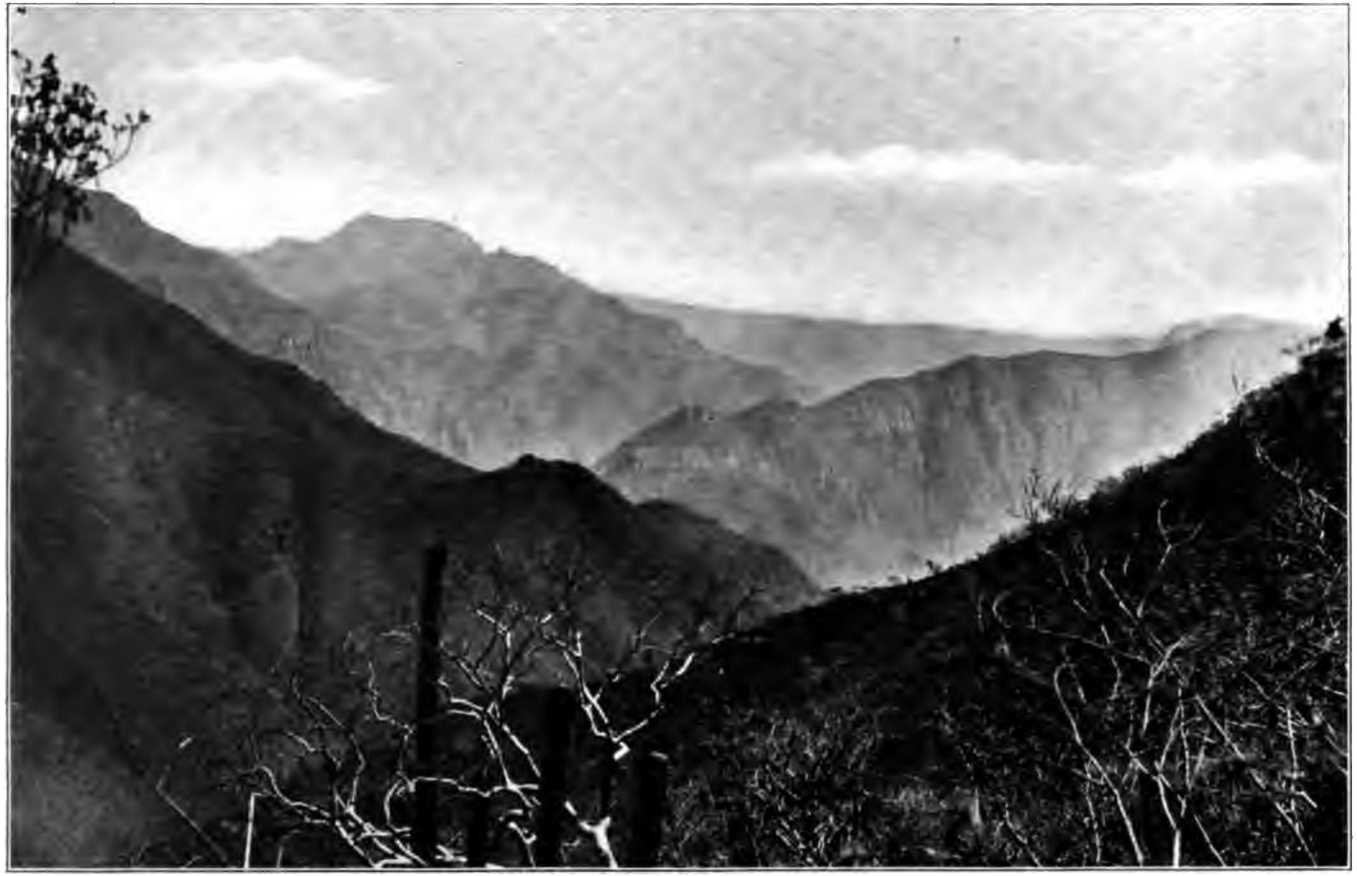
On the trail, on the western slope of the plateau. The line of mules with their variously shaped loads is typical of the movement of a pack-train.





Photograph by the Author.

Escarpments of the western edge of the plateau as seen from the west. The amphitheater-like form of the valley may be



Photograph by the Author.

Typical view in the heart of the Sierra Madre.

Typical view in the heart of the Sierra Madre.

Photograph by the Author.

branching structure characterizes their arrangement. The strata exposed in the mountain peaks lie, for the most part, in a relatively horizontal position, although broad synclines and anticlines are, at times, well marked. A distinct bedding is observable in the structure of many of the peaks. These beds are often of great thickness (200 to 500 feet), and usually lie conformably upon one another, although evidences of a quaquaversal structure are sometimes seen. Extensive faults were observed in one or two instances, but no opportunity was afforded to study them in detail.

Of the exact nature of the rocks little can be said, as they were, for the most part, only seen from a distance. While the structure outlines of many of the peaks strongly suggest sedimentary rocks, eruptive rocks probably prevail. Ordoñez, in his map of the rhyolites of Mexico,* represents this part of Mexico as characterized almost entirely by rhyolites. Upon what observations his conclusions are based, however, he does not state.

In going from the summit to the base of the peaks and vice versa, all gradations of temperature were experienced, from cold temperate to tropical. At the Ciudad ranch a snowstorm raged, while at Ventanas orange-trees were in bloom. Another change indicating differences of temperature was one in the color of the soil, which on the higher levels was yellow, and on the lower red. The western slope immediately along the edge of the plateau bore abundant vegetation, which at the lower levels was of a rank, semitropical character, with many brilliant flowering plants. Bird and insect life was extremely abundant as well. Passing westward, however, the character and amount of vegetation showed a rapid change to semi-arid conditions. Cacti and a few low shrubs succeeded the rank growths of the western slope and bird and insect life became scanty as well. These conditions prevail, the writer was informed, quite to the coast, so that it is evident that rainfall over the mountainous tract is slight. By means of irrigation, however, tropical fruits can be easily raised in the valleys, one "rancho" of this sort being conducted near Ventanas. Lemons grow wild about Ventanas, and many of the cacti bear fruits which are used for food.

It is probable that the aridity of this area is caused by the warmth of the land being such as to prevent cooling of the winds from the Pacific to a sufficient degree to produce precipitation until they have reached the summit of the plateau. From this point to a considerable distance eastward, a comparatively abundant rainfall takes place. The case seems somewhat analogous to one cited by Dana from Oahu,* where chilling of the moisture-laden winds is accomplished by a cliff so steep that precipitation does not take place until the winds have passed beyond the summit, and the rainfall accordingly takes place almost wholly upon the leeward slope.

---

*Boletin d. Inst. Geol. de Mexico, No. 14.

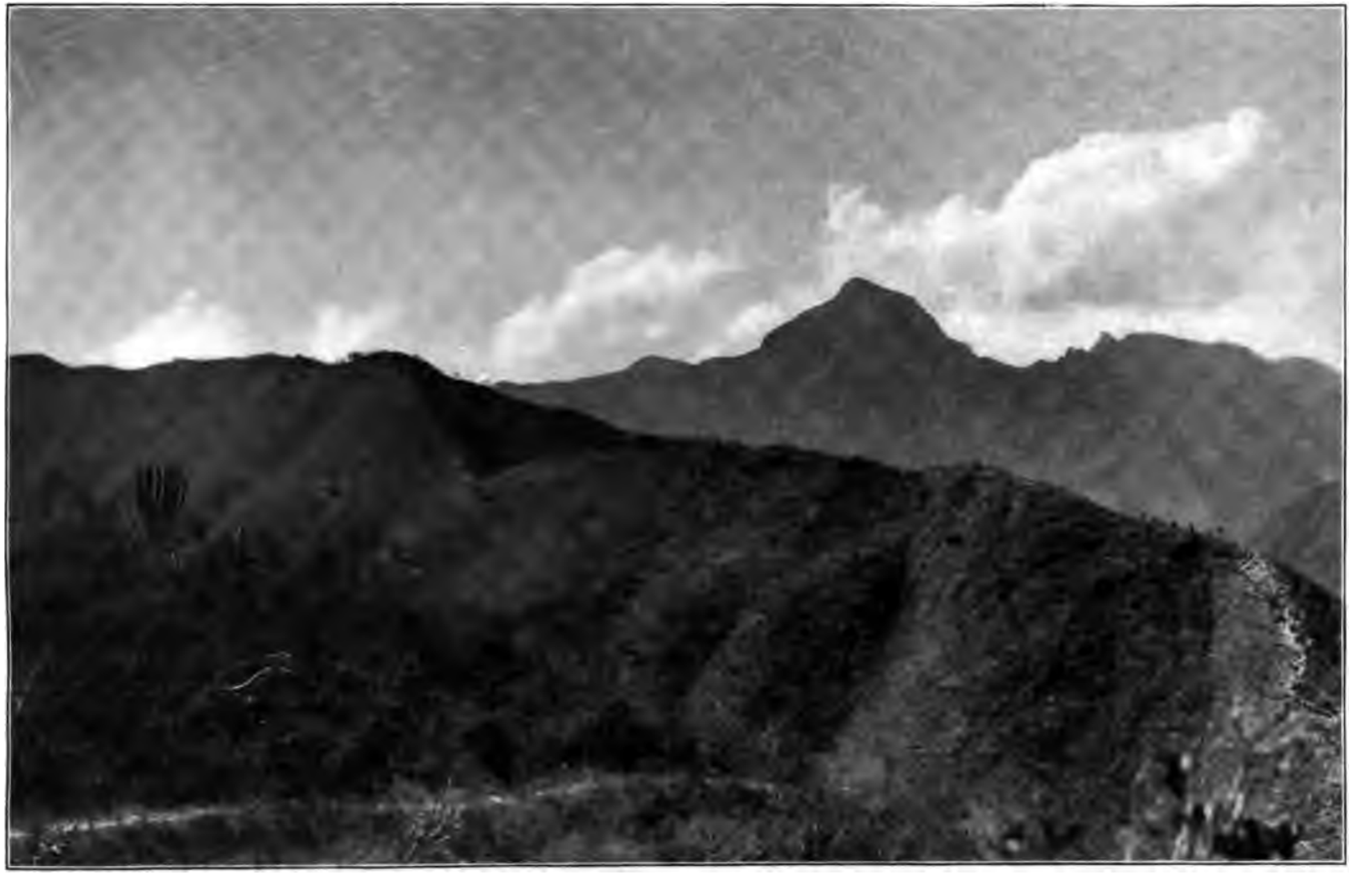
Ventanas is a small mining-camp of about six hundred inhabitants. The name Ventanas, meaning "the windows," refers to two large rounded orifices to be seen piercing a mountain wall some distance south of the town. By this name the town is commonly known, although its official designation is Villa Corona. It is situated by the side of the Rio del Presidio, sometimes known as the Mazatlan, a swift, wide stream, fordable in the dry season but in the rainy season rising to such a height that supplies must be drawn across upon a wire cable stretched for the purpose. The elevation is about 2,000 feet above the sea level, and the situation about equidistant between Durango and Mazatlan.

The principal mines in the vicinity have been operated for a number of years by the Ventanas Mining and Milling Company, an American corporation. The ores are chiefly antimonial sulphurets of silver, stephanite being the most abundant and characteristic silver-bearing mineral. Only ores of high grade are mined, it being impossible under such disadvantages of transportation to work low-grade ores at a profit. Some of the richest ores are stated to carry a value as high as 500 ounces silver, and 10 ounces gold to the ton. The most important mines are situated at a level of about 3,500 feet. Workings near the summit of the peaks, although often promising good returns, have not proved remunerative. This accords with Weed's observation,† that the profitable mines are in the underlying andesitic rocks. At La Concepcion mine the ore occurs in a well-defined vein 8 to 10 feet wide. The gangue is a tough, hard, white quartz, in which stephanite and a considerable amount of chalcopyrite and pyrite are distributed. The rock adjoining the vein is of a highly siliceous character, resembling a quartzite. Dotted throughout it, however, occur flecks of other metamorphosed minerals, indicating that the rock is in reality an andesite highly impregnated with silica. The mining is done by hand and the ore packed on burros to the mill located in the village. The river here furnishes both power and water for leaching the ores.

---

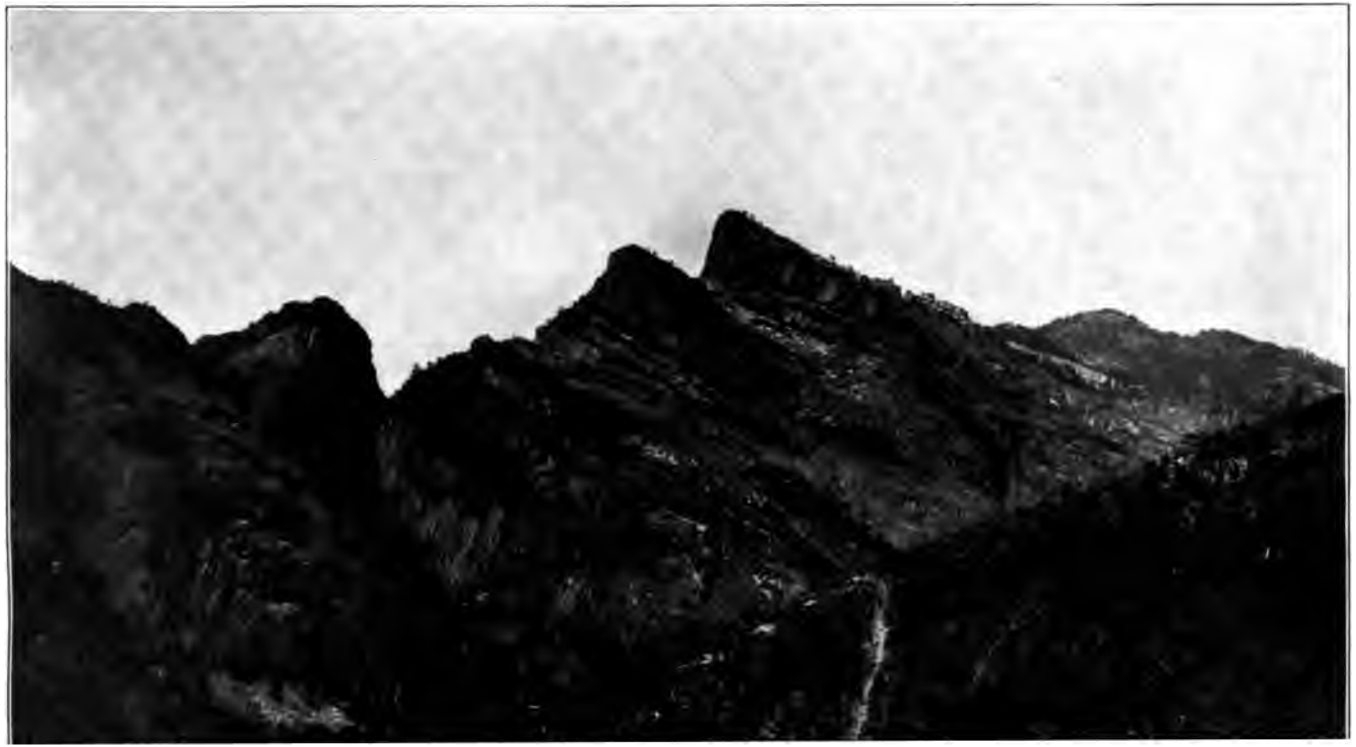
*Manual of Geology, 1895, p. 179.

†*Op. cit.*, p. 446.



Photograph by the Author.

Peaks and ridges south and east of Ventanas. Two small white spots in the middle background of the picture show the location of two orifices in a mountain which give the name of Ventanas, "the windows," to the town. The trail appears in the foreground



The extraction of the silver was accomplished at the time of the writer's visit, by the lixiviation process as follows: The ore was crushed in a Blake crusher, then mixed with from 3 per cent to 6 per cent of common salt and ground through Cornish rolls. It was then roasted in a revolving cylinder. After roasting, the base metals were leached out with water, and hyposulphite of soda added to dissolve the silver. To this was added, in order to precipitate the silver, a solution of calcium sulphide, made by burning together quicklime and flowers of sulphur. This precipitated the silver in the form of a black sulphide, which was drawn off, again roasted, and finally fused in the melting-pot and run into bars, in which form it was carried by pack-trains to Durango.

As previously stated, the region traversed is practically uninhabited. Climatically it is not inhospitable, but topographically it opposes tremendous barriers to traffic. How great these barriers are throughout the extent of the Western Sierra Madre may be judged from the fact that of seven railway lines in Mexico, with western terminals north of the Isthmus of Tehuantepec, not one has yet reached the west coast. These barriers would not of themselves probably be so great as to absolutely prevent the construction of railway lines or other roads if the small size of the area to be made available and the lack of good harbors on the coast did not considerably limit the inducements to such enterprises. On account of the lack of good harbors and productive soil on the coast however, the resources to be depended upon for developing the country must be almost wholly those of the interior. These resources include mineral wealth, of which there is undoubtedly much yet unknown, the timber resources afforded by the great forested areas, and the extensive areas which could be utilized for grazing. Whether, under the conditions, these resources can be developed with profit remains to be seen.

As regards population the region seems to have lacked in ancient times as well as now. While other parts of Mexico not now inhabited afford evidences of former habitation by man, this is not the case with this region, according to Lumholtz,* who searched unsuccessfully for any traces of a former population. In the valleys to the north and south of the region, however, he found occasional villages inhabited by remnants of the northern Aztecs, intermingled with Tepehuanes and Coras. These Indians, especially the Tepehuanes, he describes as having remarkable powers of endurance.

---

*Op. cit., p. 451.

THE CERRO MERCADO.

The Cerro Mercado, or Iron Mountain, is a hill largely made up of solid iron ore. It is situated three-quarters of a mile northeast of the City of Durango. In form it is elongated, with a roughly triangular outline, the base of the triangle lying towards the west. Its general trend is nearly east and west, or more exactly, as given by Witherbee,* N. 83° E. The hill rises abruptly above the alluvial plain upon which the City of Durango is situated, to an average height of about 300 feet, with single peaks 50 to 100 feet higher. The length of the hill is about one and one-third miles, and its average width about one-third of a mile. At about the middle of its extent in an east and west direction, an inset of eruptive rock cuts it practically in two, although the iron ore may be in contact below.

The black color of the iron oxide, of which the hill is composed, is in striking contrast to the yellow and green of the surrounding plain. The hill is almost bare of vegetation, except for straggling cacti, and its outline is bold and rugged. Steep cliffs ten to twenty feet high, and even higher, are not infrequent, and in places exhibit a distinct columnar structure like that of basalt. Such cliffs are composed wholly of ore. They bear no vegetation. From these projecting masses of iron ore, talus slopes lead, as a rule, down to the level of the plain. These slopes are generally rather steep. The talus consists largely of fragments of the ore intermingled with soil and fragments of other rocks. Among the ore fragments occur some described by Witherbee† as being rounded and nodular, and imbedded in stiff, clayey matrix. Such have probably been water worn. In a later article‡ this author states that the nodular ore extends to the east for over a mile, and to the south it was found three and one-half miles distant at a depth of 60 feet when digging for water. At this point it was embedded in a gravelly clay. There can be little doubt that these fragments have been distributed by the same fluviatile agencies which deposited the gravel.

The iron oxide, which forms the great mass of the mountain, has often been described as consisting chiefly of magnetite. This is the affirmation of Weidner§ and Chrustschoff, although the re-

---

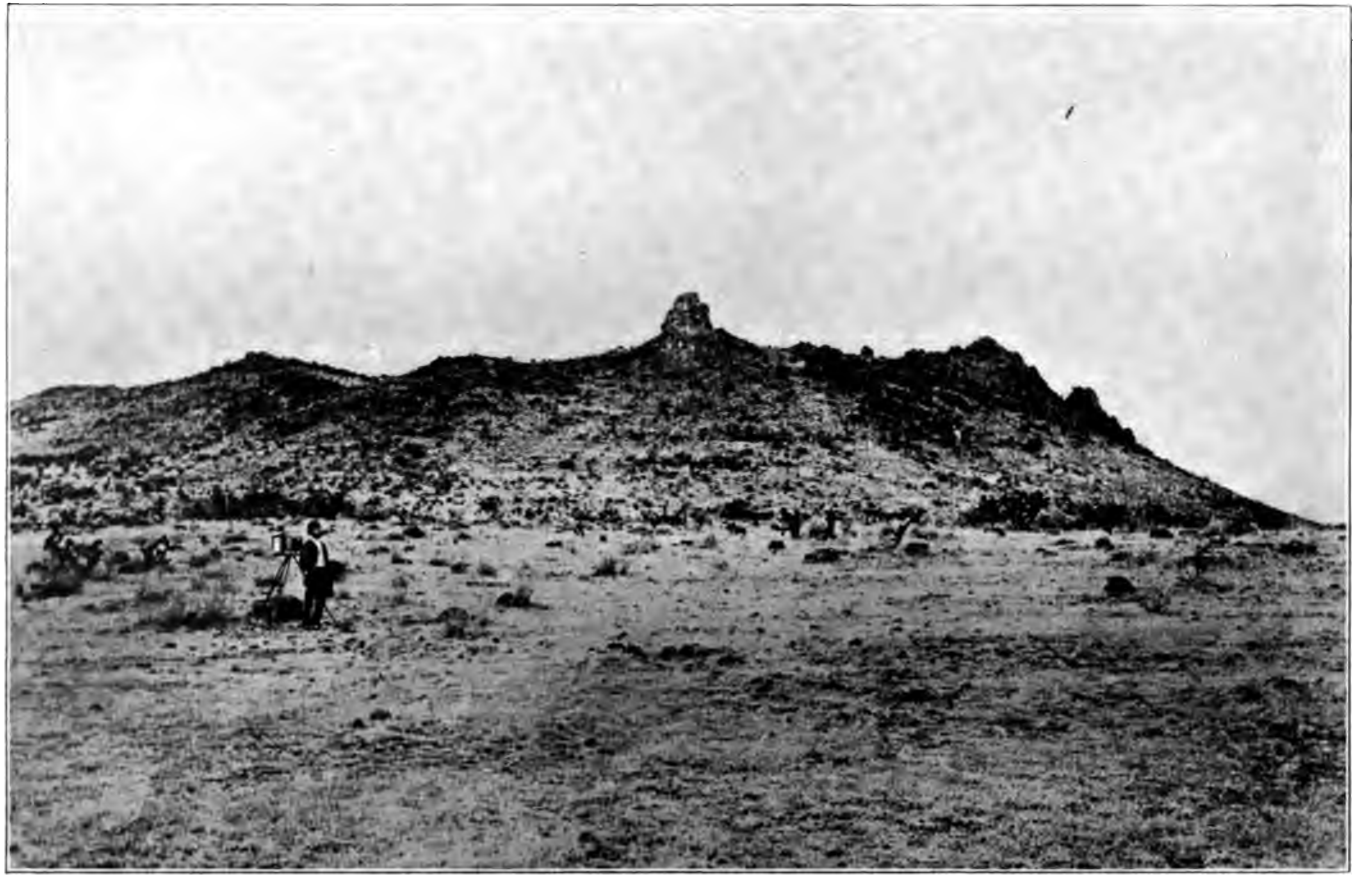
*Trans. Am. Inst. Min. Eng., Vol. XXXII., p. 156.

†*Loc. cit.*

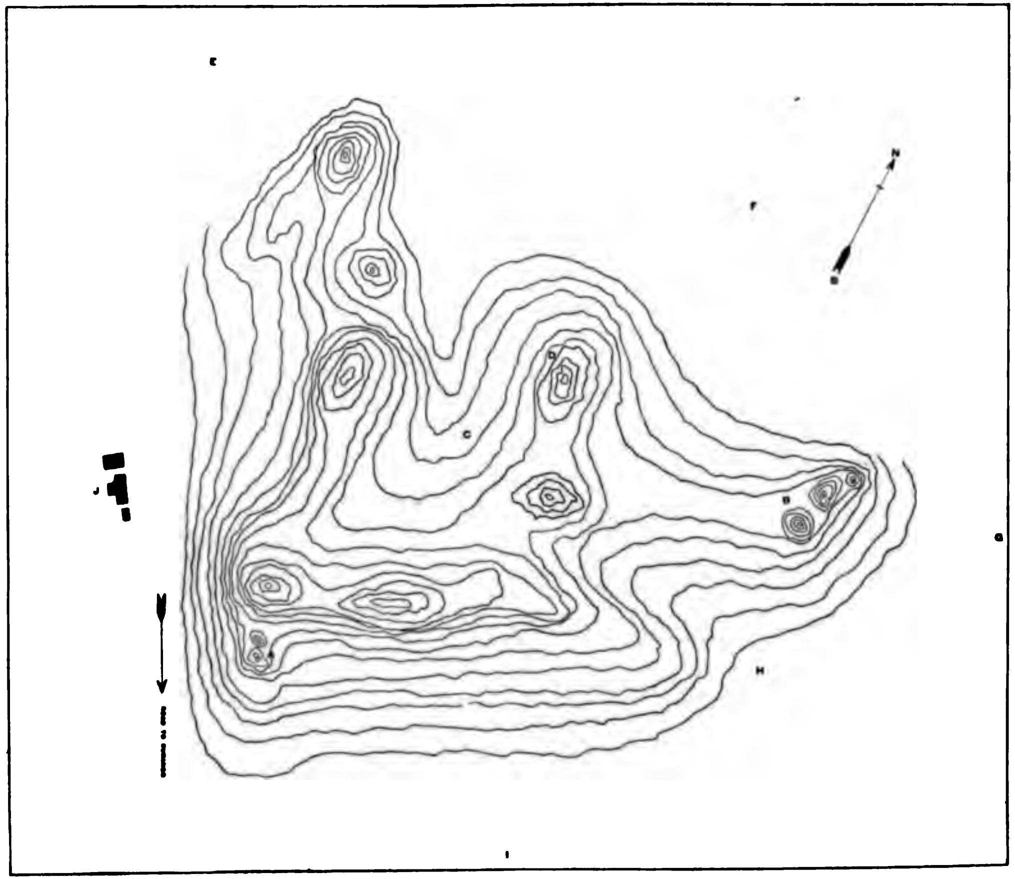
‡Mining World, March 12, 1904, p. 21.

§Report to the Mexican Minister of the Interior. Translated by Burkart, Neues Jahrbuch, 1858.

Einiges über den Cerro del Mercado, Wurzburg, 1879, p. 7.



Cerro Mercado, or Iron Mountain, as seen from the plain.



Contour sketch of the Cerro Mercado, after Birkinbine. A, Peak of iron ore; B, Peak of iron ore surmounted by cross; C, Apatite locality; D, location of shaft dug to depth of about 70 feet; E, rhyolite breccia, Mus. No. E 8184; F, rhyolite breccia, Mus. No. E 8185; G, rhyolite breccia,

ported analyses of the ore by the latter show no Fe O, an omission which has been remarked by Cohen.*

Rangel, however, states that true magnetite does not exist upon the mountain, except as its presence is indicated in small quantity by a feeble magnetism exhibited by some specimens.†

The present writer failed to find any typical magnetite on the mountain, although a black powder occurring on the northern side proved to be slightly magnetic. Moreover, in carrying a compass needle over the mountain no deflection was noticed at any point.

Witherbee states, however, that recent surveys show needle variations of from one to ten degrees.‡ Regarding the occurrence of magnetite he states in the same article, that while he once "went on record to the effect that 'there was not a cart-load of magnetite on the mountain,'" he is now of the opinion that there may be some magnetite there. This opinion is based on the needle variations above mentioned, and by magnetic grains found among the anthills. Further, of numerous samples ground up for analyses, while some were non-magnetic, others could be separated into a magnetic and non-magnetic part. Moreover, lodestone has been found at a locality west of "the cross."

It seems evident, from the above considerations, that on the whole the ore of the Cerro Mercado may be regarded as chiefly hematite, although in many cases doubtless, a mechanical mixture of magnetite occurs.

This hematite varies considerably in physical characters, being now hard and now soft, now black and now red, now specular and now earthy. Of these varieties, the hard, solid, black ore is the most abundant and forms the chief mass of the mountain. It is this which forms the prominent cliffs and columns and projecting spurs. It is essentially solid and continuous, although narrow open spaces frequently penetrate it, usually lined with octahedral crystals of martite. The hardness and toughness of this ore are such as to make the task of mining and crushing it a difficult one. It is very severe, Witherbee states, on the hard parts of crushers, and will cut into the face of the hardest steel hammers. In fact, this toughness has been a serious obstacle hitherto to the use of the ore, and has resulted in the utilization chiefly, up to the present time, of the soft red variety found at the base of the mountain.

Many analyses of the ore have been made and are quoted by writers upon the subject. Of these it will be sufficient to repeat those quoted by Witherbee* from analyses contained in the report of Robert W. Hunt, dated March 28, 1901.

---

*Zs. Kryst., Vol. 3, p. 632.

†Bol. Inst. Geol. de Mexico, Num. 16, p. 6.

‡Mining World, March 12, 1904.

	1. Per cent.	2. Per cent.	3. Per cent.	4. Per cent.	5. Per cent.	6. Per cent.	7. Per cent.
SiO_2	5.58	6.12	10.80	5.04	3.74	3.18	7.02
TiO_2	......	......	......	......	......	......	......
Al_2O_3	1.93	1.73	0.65	0.69	0.93	0.18	2.06
CaO	2.80	3.80	1.25	0.20	0.50	0.80	1.15
MgO	0.36	0.34	0.41	0.09	0.17	0.23	0.22
SO_3	......	......	......	......	......	......	......
S	0.35	0.019	0.017	0.026	0.019	0.033	0.024
P_2O_5	......	......	......	......	......	......	......
P	0.785	0.369	0.316	0.210	0.309	0.199	0.275
Fe_2O_3	......	......	......	......	......	......	......
Fe	60.48	......	59.95	65.55	65.15	65.95	60.85
Mn	0.30	0.29	0.32	......	0.13	0.30	0.26
Loss on ign.	1.06	0.80	0.16	0.44	0.84	0.80	2.08

1. Mass in place on N. boundary. 2. The "cave." 3. Drift on E. face of property. 4. Boulders in place on Ridgely peak. 5. The cross. 6. Western face of property. 7. Stock-pile at furnace.

The amount of ore in sight above the level of the plain is stated by Witherbee to be at a conservative estimate 360,000,000 tons. Explorations which have been made in depth have found no limit in this direction.

The hill has long been celebrated, its existence having first been reported in 1552 A. D. In that year a Spanish captain, Gines Vasquez del Mercado by name, having set out from Guadalajara to search for mines of gold and silver, was led to the hill by reports of its being a mountain of gold. On finding it iron instead, the name of Mercado was applied to it somewhat derisively by his soldiers.

In later years a report seems to have been quite widely circulated that the mass was a huge meteorite, and it is not uncommon to hear this stated at the present day. Weidner states that Humboldt thought it was a meteorite, but as Burkart shows, Humboldt does not say this.† Humboldt says of the Cerro del Mercado simply that it "contains an enormous mass of brown magnetite or micaceous iron,"‡ although he seems not to have visited it. In another place he refers to a meteorite found in the outskirts of Durango, which Weidner confuses with the Cerro Mercado. More general and persistent than the belief in the meteoric character of the hill seems to have been one that it would prove rich in gold or silver, and many pits have been dug and many attempts made at va-

---

*Trans-Am. Inst. Min. Eng., Vol. XXXII., p. 162.

†Neues Jahrbuch, 1858, p. 773.

‡Kingdom of New Spain. Translation of John Black, Vol. 3, p. 297.

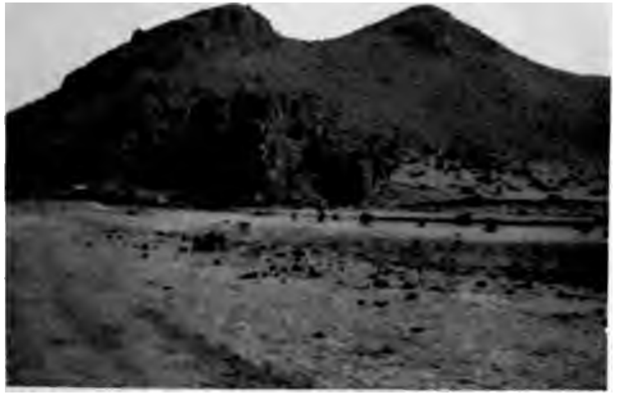


FIG. 1.

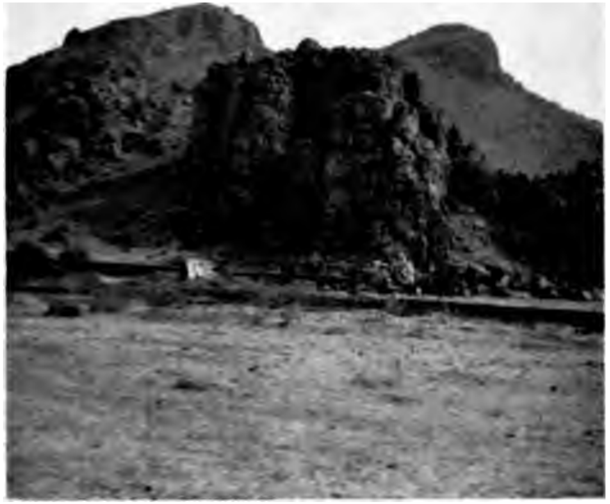


FIG. 2.

Photographs by S. E. Meek.

Fig. 1. Cliffs and exposures of iron ore at western end of Cerro Mercado.
Fig. 2. Nearer view of same. The columnar structure of the ore is apparent.

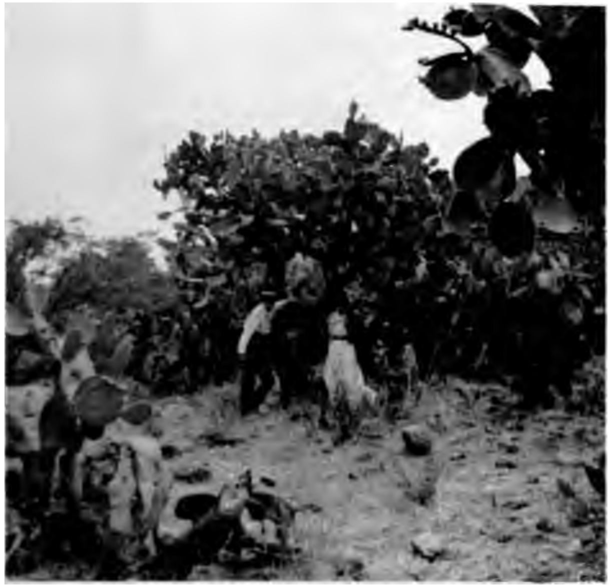


FIG. 1.

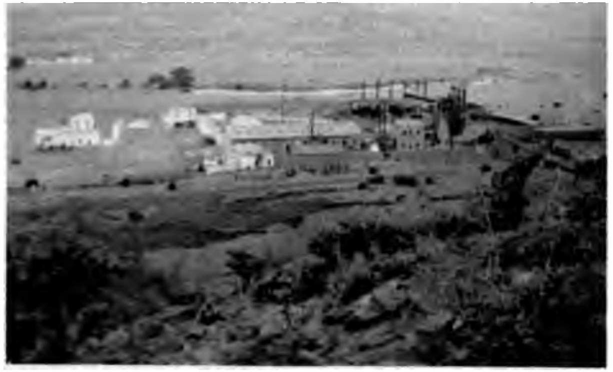
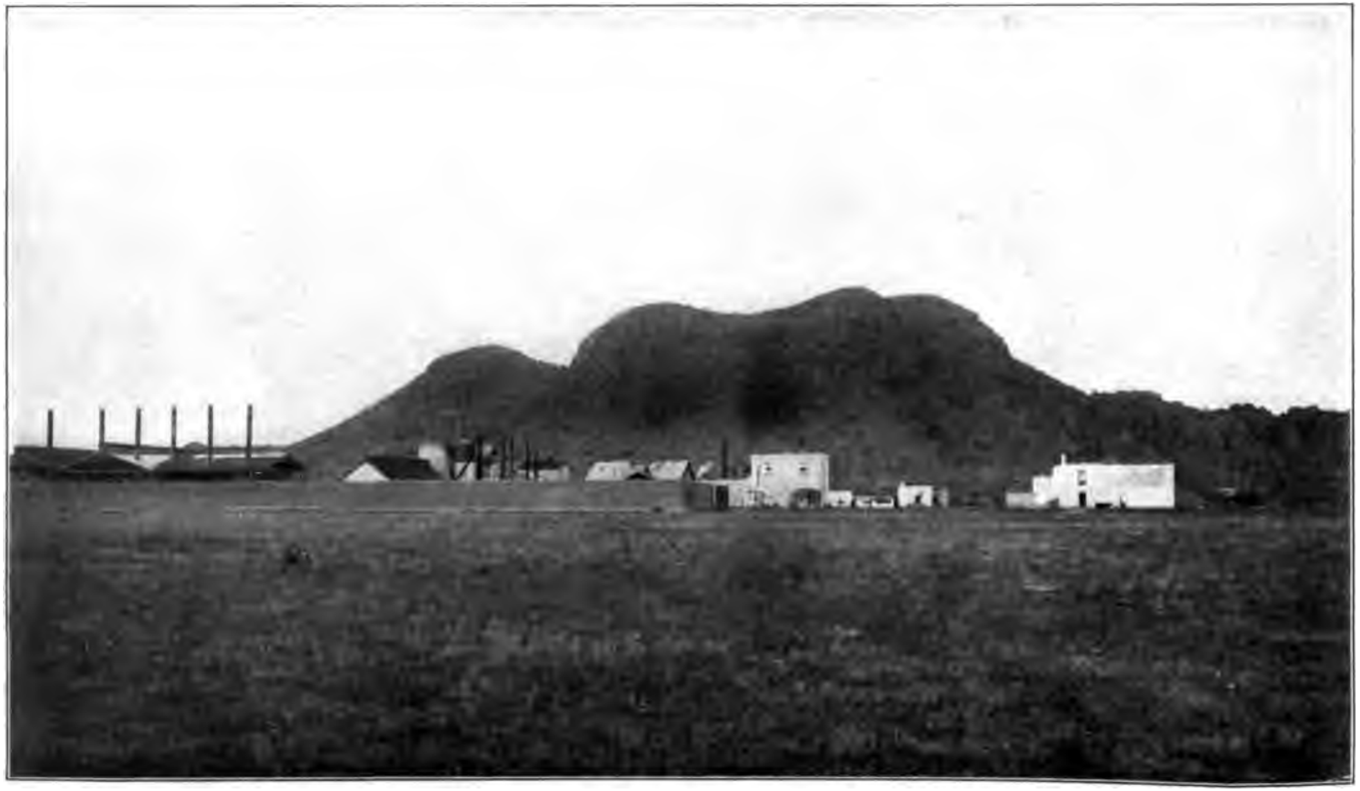


FIG. 2.

Photographs by S. E. Meek.

Fig. 1. Cactus growth on Cerro Mercado.

Fig. 2. Works of Mexican National Iron and Steel Company, seen from the Cerro Mercado.



Cerro Mercado, as seen from the west, and works of the Mexican National Iron and Steel Company.
(Published by courtesy of the American Institute of Mining Engineers.)

rious times to extract these metals from the mountain. Birkinbine mentions one shaft 70 feet deep made through solid ore on the north side of the mountain, with drifts extending from its bottom,* which was probably sunk with the hope of finding precious metals. In the iron ore of the Murca ranch, a deposit of similar origin to the Cerro Mercado and connected with it, Witherbee reports† that as much as 9 ounces of silver and 0.5 ounces of gold have been found.

The first serious attempt to use the deposit as a source of iron seems to have been made in 1828, when an English company under patronage of the Governor of Durango, established some works on the bank of the Rio Tunal, five miles south of Durango, on a site known as Piedras Azules. Motive power was secured by a dam across the river, and a blast furnace was erected. First attempts to obtain iron from the ore were however unsatisfactory, and the project was soon abandoned. In 1834 a new company took the matter up and by constructing a blast furnace of different type, succeeded in obtaining a product of 5,000 to 8,000 pounds of iron a week. With some intermissions a small output of iron from these works has been maintained ever since. About 1882 a larger plant, shown in Plate LXIX., was erected close to the western end of the mountain. Successful operations were not conducted here until 1888, and only within the last five years has a steady production been maintained. A full description of the plant and of the iron produced is given by Witherbee.‡ The fuel used is charcoal, or charcoal and coke, the charcoal being made largely from the mesquite. For flux, limestone, obtained about twenty-five miles distant on the line of the Mexican International Railroad is used. The iron produced is said to have exceptionally good chilling qualities and to be very strong.

Besides the use of the ore as a source of iron, it has been found valuable as a flux for the smelting of lead, and is employed extensively for this purpose in various smelters in Mexico. Such a use of the ore began with the advent of the railroad to Durango in 1893, and since that time more than 400,000 tons have been so employed.

Several well-defined mineral species occur upon the Cerro Mercado and have been more or less described.

Chrustschoff§ reports the following: magnetite, hematite, quartz as rock crystal and amethyst, chalcedony, opal, phenacite, pycnite, fluorite, and garnet. The magnetite is described as occurring in the form of octahedrons, or of octahedrons modified by the cube and trapezohedron. The hematite is described as showing striations which indicate rhombohedrons. The phenacite is described as occurring in crystals, in part imbedded in a quartz porphyry and in part loose in clay. The crystals are said to be generally dull and whitish on the surface, but clear and wine-yellow in color within. An analysis of the phenacite is given, but some peculiarities of this, as pointed out by Cohen,[*] throw doubt not only on the analysis, but also on the report of the occurrence. The pycnite is stated to occur in stalk-like aggregations lacking determinate crystal form and yellowish brown in color. The fluorite is described as occurring in very beautiful crystals of green and blue colors, having generally the cubical form, at times modified by the tetrahexahedron and hexoctahedron. The garnet is described as occurring in small transparent crystals of rose color. No mention of the occurrence of martite or apatite is made by this writer.

---

*Trans. Am. Inst. Min. Eng., Vol. XIII., p. 191.

†Trans. Amer. Inst. Min. Eng., Vol. XXXII., p. 158.

‡Trans. Amer. Inst. Min. Eng., Vol. XXXII., p. 158.

§*Op. cit.*, pp. 44–50.

Martite from the mountain was described by Silliman.[†] Dana mentions this martite, also phenacite,[‡] apatite,[§] topaz, magnetite, cassiterite, and durangite,[‖] references to authorities for the latter occurrences not being given.

Rangel reports in addition to hematite—of which he notes solid, specular, micaceous, and ochreous varieties—martite, quartz, apatite, topaz, and a phosphate of iron occurring in the form of a yellowish powder.[¶]

The topaz, or pycnite ("pricnita"), is described by Rangel as being in the form of small, symmetrical rhombic prisms, presenting various prismatic faces, and at one extremity combinations of pyramids and domes, while the other is terminated by the base. The color of the crystals is described as hyaline white, rose, or pale yellow.

The apatite is described as occurring in simple crystals, either alone or in company with oxide of iron; likewise as in veinlets or masses in which well-formed crystals of large size occur. The best crystals are said to occur at the point called "Cueva de los biriles" (Cave of the beryls?). The color of the crystals is described as honey-yellow to greenish yellow, and their length as nine or ten centimeters. The crystals are said to present a multitude of prismatic facets, terminated by an irregular pyramid of six faces, of which two or three are often imperfect or wanting. These crystals are said to be often confounded in Durango with topaz.

---

[*] Zs. Kryst. Vol. 3, p. 633.

[†] Am. J., Sc. 24, 375, 1882.

[‡] System of Mineralogy, 1893, p. 463.

[§] System of Mineralogy, 1893, p. 767.

System of Mineralogy, 1893, p. 405.

[¶] *Op. cit.*, p. 6.

Of the above, only martite, quartz, chalcedony, and opal were collected or observed by the writer. Apatite, however, was collected on the mountain by S. E. Meek of the Museum in 1903, and an excellent suite of these crystals now forms a part of the Museum collections.

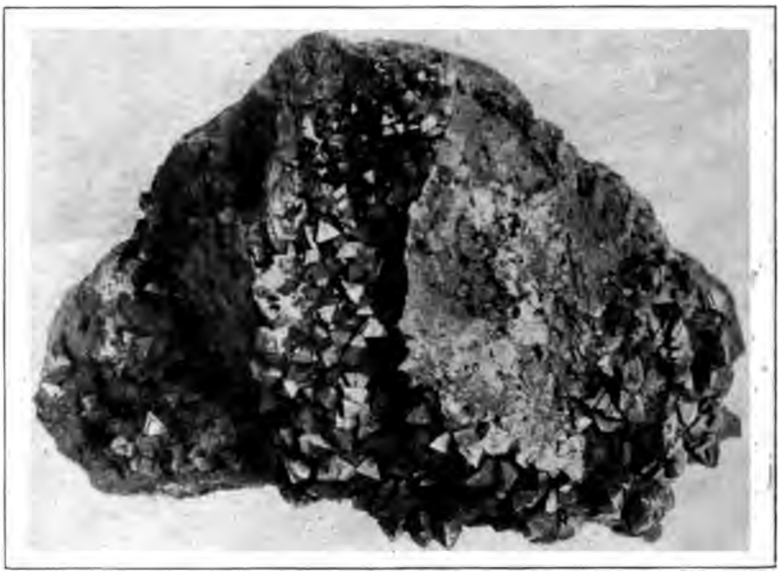


FIG. 4. Martite. Cerro Mercado. × 1.

The martite collected by the writer (Mus. No. M 5497) was in the form of simple crystals attached to masses of the solid ore. The appearance of a typical specimen is shown in Fig. 4. The specimens were all obtained from the west side of the mountain, where the crystals occurred in groups, generally lining cavities. The crystal form was invariably that of unmodified octahedrons. In size the crystals varied from those measuring only a millimeter on a side to some measuring twenty to twenty-five millimeters. Their color was iron-black, with occasional coatings of brown iron oxide. None of the crystals nor their powder was attracted by the magnet, the behavior of the powder in this respect differing from that examined by Silliman. The color of the streak and powder was the familiar cherry-red of hematite. Like the ore to which the crystals are attached, and from which they probably do not differ essentially in composition, the crystals are hard and tough, the hardness being 6.5. To the naked eye the crystals appear of ordinary homogeneity and purity, but on polishing a surface and examining it with a moderate magnifying power, the homogeneous character disappears. A considerable number of inclusions is seen, indicating that the crystal is not of uniform composition. The inclusions are in the form of reddish patches, usually with straight outlines, and often triangular or elongated in shape, or they appear as spots of tuberose, irregular character elevated above the surface. These inclusions probably indicate different stages in the process of alteration of the mineral, but just what is not known. An analysis of some of the crystals was made by Mr. H. W. Nichols, those selected for the purpose being such as appeared homogeneous. The analysis gave the following results:

Fe_2O_3	97.26
$Fe\ O$	0.78
H_2O	1.21
$Ti\ O_2$	Trace
$Mg\ O$	Trace
$Si\ O_2$	0.25
S	0.69
	100.19
$O = S_2$	0.17
	100.02

No lime, copper, manganese, or phosphorus were found, although looked for. The analysis shows that inclusions of other minerals occur in the martite, chiefly, however, compounds by alteration. Exactly what minerals the different compounds may represent it is impossible to say, but the following may be suggested as a reasonable constitution for the martite crystals:

Hematite	90.12
Limonite	8.35
Pyrite	1.29
Quartz	0.25
	100.01

The presence of pyrite is indicated by the content of sulphur and an almost exact equivalent of Fe O. Moreover, the powder of mineral when heated gives off a slight sublimate of sulphur. If pyrite is present in small quantity in the martite crystals it is possible that the martite is a pseudomorph after that mineral. Silliman,* however, states that he found nothing in his examination of

---

**Loc. cit.*

the martite crystals to prove that they were derived from pyrite and Chrustschoff remarks an entire absence of pyrite. Yet, derivation of the martite from magnetite seems equally unverified, since crystals of magnetite from the mountain have not yet been positively identified, and the martite contains only a trifling quantity of FeO. The octahedral form shown by the martite crystals is to be sure more common to magnetite than to pyrite, but it is not uncommon to pyrite.

It seems uncertain as yet, therefore, whether the martite originated from pyrite or magnetite, or whether indeed it may be a dimorphous form of hematite. Still, the weight of evidence seems to be in favor of its origin from magnetite.

The apatite crystals collected by S. E. Meek (Mus. No. M 7668) were obtained on the northern side of the mountain at a single locality, where they occur loose in a sandy soil either free or implanted upon or imbedded in pieces of quartz. The pieces of quartz also lie loose in the soil and are evidently derived from the breaking down of some older and larger mass. The quartz is usually chalcedonic in character, but in some specimens shows slender crystals a few millimeters in length. The apatite crystals are prismatic in habit, and range from 2cm. in length down. They are transparent except where coated with iron-oxide or silica. Their color is that of the true asparagus stone, viz., pale greenish to honey-yellow. On heating a crystal or fragment, it at first turns darker yellow in color, but at a higher temperature all color gradually disappears, and is not regained on cooling. The dominant planes on the crystals, and those constantly present, are the prism of the first order, *m* $(10\bar{1}0)$, and the unit pyramid *x* $(10\bar{1}1)$. Of these the prismatic planes are usually flat and bright, but the pyramidal planes present a cracked and often irregular surface. This cracked appearance is found on examination to be due to a cleaving or parting parallel to the pyramidal surface, broken in turn by other cleavages at right angles. The

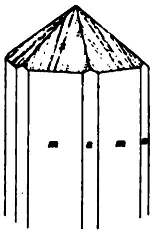


FIG. 5. Apatite. Cerro Mercado.

latter often give a striated appearance to the surface of the planes, the direction of the striæ being that of the intersection of two planes of the pyramid of the second order. In other crystals the pyramidal planes present a concave or otherwise irregular surface. The pyramidal planes are rarely present in full number, only two or three occurring commonly. The usual habit of the crystals is shown in Fig. 5. No doubly terminated crystals were found. As a modifying form, the prism of the second order *a* $(11\bar{2}0)$ is common, occurring with planes sometimes narrower and sometimes as broad as those of the fundamental prism. The planes usually have a luster and surface like those of the first order prism. The only other modifying form found was a plane of the 4-4/3 pyramid *n* $(31\bar{4}1)$ found on a single crystal. The symbol of this plane was determined by its position and the following measurements:

	Measured.	Calculated.
$m : n$ $(10\bar{1}0 : 31\bar{4}1)$	22° 41	22° 30

Numerous attempts were made to secure an accurate measurement of $m : x$ $(10\bar{1}0\ 10\bar{1}1)$, but owing to the imperfect surface of the latter planes success was obtained in only a single case. This afforded, however, a very accurate measurement, and gave the value 49° 43′. This would correspond to a value for $c : x$ $(0001 : 10\bar{1}1)$ of 40° 17′. The Cerro Mercado apatite has therefore a large axial angle. Ordinarily, as pointed out by Palache,* apatites with large axial angle are free from chlorine. A qualitative test of the Cerro Mercado apatite, however, made by dissolving it in nitric acid and adding silver nitrate, gave a precipitate of silver chloride sufficient to indicate the presence of an appreciable quantity of chlorine. The specific gravity of the apatite obtained with a chemical balance on the pure crystals gave the value 3.222. The fracture of the crystals is highly conchoidal.

Of the rocks associated with the iron ore of the Cerro Mercado, detailed description has been given hitherto by only two authors, Chrustschoff† and Ordoñez.‡ Chrustschoff describes several varieties of quartz porphyry and quartz porphyry breccias occurring mostly on the eastern, northern, and higher portions of the hill. One of the quartz porphyries is said to contain phenacite in sufficient quantity to form practically an essential constituent. No such rock was noted by the present writer, and so remarkable an occurrence needs confirmation. Other rocks described by Chrustschoff are a hornblende-bearing granite stated to occur on the western part of the hill, a black basalt, an obsidian and a diabase forming a hill to the north. The exact localities of these rocks are not given. By Ordoñez, the rocks of the Cerro Mercado are described, aside from the tuffs, under the general term of rhyolites. Their color is said to vary from gray to red and violet. The ground mass is described as being hard and compact, and often more or less devitrified. At times phenocrysts are said to be lacking, giving the rock a more or less felsitic appearance, and again to be so abundant as to produce porphyries. The phenocrysts are described as quartz and feldspar with some crystals of the latter reaching a length of one centimeter. Plates of tridymite are noted lining small cavities. The feldspar is stated to be partly sanidine and partly oligoclase. Witherbee gives two analyses of "the country rock, '*cantera*,' or rhyolite," and two of "white clay," from the mountain.* The analyses are incomplete, however, and are obviously intended to be merely suggestive. Moreover, no exact statement is made as to the localities from which they were obtained.

---

*Proc. Am. Acad., Vol. XXXVII., p. 528.

†*Op. cit.*

‡Bol. d. Inst. Geol. de Mexico, No. 16, p. 11.

While no detailed study of the associated rocks of the Cerro Mercado was possible to the writer upon the ground, owing to lack of time, hand specimens were collected at several different points, of which it has been possible to make careful study in the laboratory. These rocks include four breccias, collected at different points along the northern side of the mountain, and two porphyries, obtained on the southern side. The localities where they were collected are shown upon the contour map, Plate LXVI. These specimens probably represent pretty fairly the important varieties occurring upon the mountain and in its vicinity. The breccias, or tuffs, such as were collected, characterize the whole northern side of the mountain, and extend eastward for fully half a mile. They vary constantly in color and compactness, their general color being red, but at times violet and gray occur. These differences doubtless mark variations in the degree of oxidation of the iron, for if a portion of a red fragment be heated in the reducing flame its color becomes violet or gray. At one point in the area, evidently as the result of leaching, the rock is chalk-white in color. Other evidences that the area has been considerably permeated by circulating water are seen in seams and patches of chalcedony, or milky quartz, which appear in numerous places. This chalcedony is generally pale in color, and translucent.

Of the above breccias, that collected farthest west (Mus. No. E 8184), E, Plate LXVI., is dull brick-red in color with lighter spots. Although appearing of a fairly uniform color and texture when seen in the rough, a polished surface makes evident that it is of fragmental origin. The fragments have angular or slightly rounded outlines, and average a few square millimeters in diameter. They vary in texture, some being fine-grained and compact, others scoriaceous. The border of each fragment is usually marked by a deeper red line. Some of the fragments show that the rock from which they were broken had a distinct flow structure. Irregular grains of transparent quartz are scattered through the whole mass of the rock, seeming, in some cases, to be a primary constituent of the larger fragments, and in others to be constituent grains. As they lack any distinct crystal outline, however, they are probably all fragmental. A quantitative determination by Mr. H. W. Nichols of the amount of silica in this rock gave $Si O_2 = 72.56$ per cent.

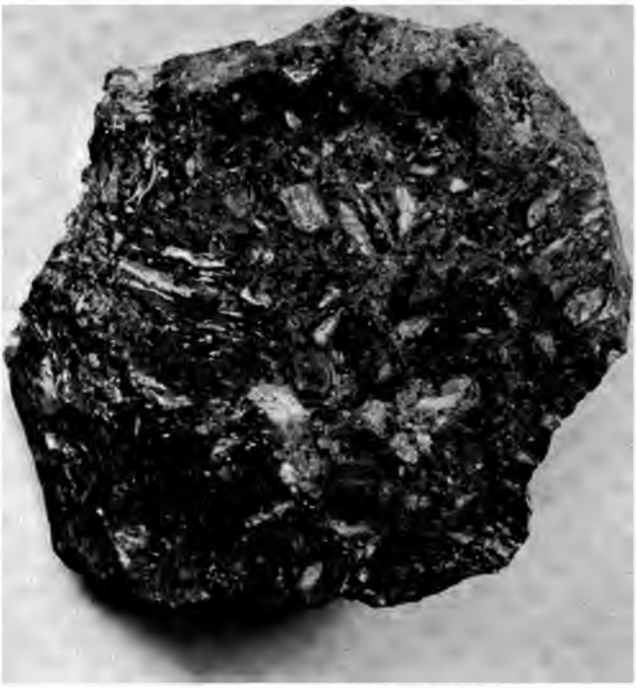
---

*Mining World, March 12, 1904, p. 21.

In the area covered by this breccia a rock, already mentioned as being of a chalk-like appearance, forms an extensive bed. The hand specimen of this (Mus. No. E 8186) is chalk-white in color and friable so as to soil the fingers when handled. It can be easily crushed in a mortar, and is used locally to make fire-brick. It is harsh to the feel, porous, and of low specific gravity. Before the blowpipe it is infusible. It is also anhydrous, giving off no water upon heating in a matrass. A chemical examination by Mr. H. W. Nichols showed the composition to be nearly pure silica, an approximate quantitative determination giving $Si O_2 = 98$ per cent. The rock is apparently a leached tuff, the leaching having removed nearly all other ingredients except the silica. Indications of a former fragmental structure are afforded by small angular cavities in the rock partly filled by pumiceous remains. A peculiar feature noted during the chemical examination of the rock was that a heavy white fume was given off when fragments were heated in a closed tube. On breaking open the tube this fume disappeared and a pungent odor, resembling that of SO_3, was obtained. The fumes tend to form a ring within the tube, and when they are driven into the water the water becomes acid.

The hand specimen (Mus. No. E 8185), taken east of this from about the middle of the northern side of the mountain, F. Plate LXVI., is likewise a breccia, or coarse tuff, differing from that occurring west in being more plainly fragmental in character and in having a lavender color. The appearance of a polished surface is shown in Plate LXX., Fig. 1. In spite of its clastic origin, and although numerous irregular pores about the size of a pinhead are scattered through it, it is tough and fairly compact. The different fragments of which the rock is composed vary in size and color and shape.

Fig. 1.



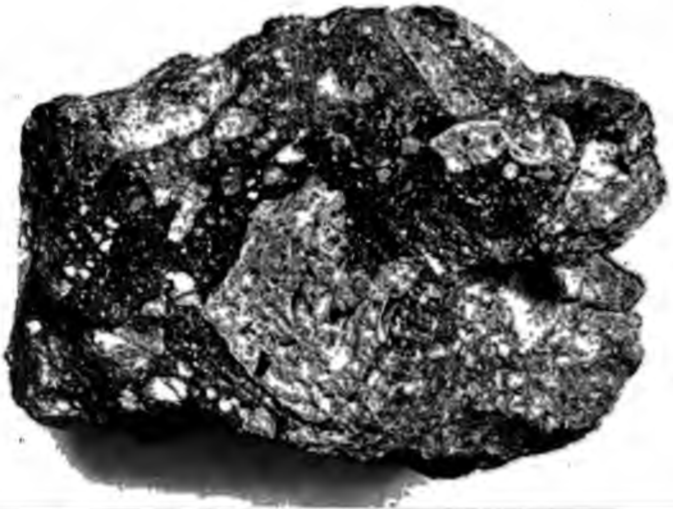


Fig. 2.

Fig. 1. Rhyolite breccia, Mus. No. E 8185.
Fig. 2. Rhyolite breccia, Mus. No. E 8183.

Their outlines are angular and their shapes polygonal to pyramidal. Some are scoriaceous and some compact. The variations in color are from light to dark lavender and brown. As in the rock previously described, minute grains of quartz with irregular outlines are scattered through the mass.

A fourth hand specimen (Mus. No. E 8183) illustrates the prevailing rock at the eastern end of the mountain. It was collected at the point marked *C* in Plate LXVI. The appearance of a polished surface is shown in Plate LXX., Fig. 2. This is also a breccia, and is of coarser texture than any of those previously mentioned. It has a general brick-red color, but many of the included fragments are lavender or white. These differences of color mark the fragments of which the rock is composed. The fragments are irregular in shape and have angular outlines, there being no visible signs of attrition previous to consolidation. In size they range from an inch (2.5 cm.) square to minute particles. They also vary considerably in texture, some, usually the larger ones, being scoriaceous, while others are fine-grained and compact. The scoriaceous portions are somewhat friable, and are the first portions to weather out. When this takes place cavities are left. Throughout all portions of the rock, as in the specimen previously described, are scattered irregular grains of transparent quartz.

Under the microscope the three breccias above described present nearly the same appearance. The ground mass is a devitrified glass varying in coarseness of grain, the variations usually appearing in ramifying areas. There are few phenocrysts to be seen. Those visible are usually quartz, but occasionally feldspar. They lack, as a rule, regular outlines, and seem to have little or no genetic relation to their surroundings. Some of the quartz grains, however, have hexagonal outlines, and some of the feldspars are lath-shaped. In portions exhibiting flow structure the lines of flow often bend around a phenocryst, showing a unity of origin of the two. Spherulites, or fragments of them, occur occasionally, especially in portions of the rock exhibiting flow structure.

It will be seen from the above descriptions that the rock along the northern side of the mountain is fragmental in character, and that it increases in coarseness toward the east. In origin it may be of the nature of a flow breccia, and of the same age as the other rhyolites of the mountain.

The rocks upon the southern side of the mountain show none of the clastic character of those on the northern side. On the contrary, they are homogeneous and of primary origin. Two specimens were collected to illustrate these, one at the point marked H upon the contour map, Plate LXVI., the other farther to the south, at the point marked I. The latter (Mus. No. E 8192) is of a light gray color, and has the typical rough feel of trachyte. As it carries an abundance of quartz, however, it is rather to be considered a rhyolite. The gray color as seen megascopically belongs to the ground mass, for the phenocrysts are practically colorless. These phenocrysts are quartz and feldspar in about equal proportion. The quartz individuals have irregular outline with a hardness of 7 and show no cleavage, while the feldspar is in lath-shaped forms with shining cleavage surfaces. A pleasing feature of the feldspar individuals is a pearly opalescent reflection like that of moonstone, which they exhibit, especially when wet. In size both quartz and feldspar individuals reach a length of about 2 mm. and average perhaps 1 mm. in length. In texture the rock is somewhat open, small pores and cavities being not infrequent. Porosity is further shown by the fact that when a piece of the rock is immersed in water, bubbles continue to rise for a long time. Under the microscope the ground mass shows the characters of a devitrified glass. It has a microgranular structure as a whole and exhibits no elongated microlites. Opaque, brownish, amorphous particles presenting no farther discrete characters, cause a considerable clouding throughout the ground mass. As phenocrysts occur abundant large quartz and feldspar individuals, but femic minerals seem to be lacking except for occasional grains of magnetite. These latter lack regular outline, and show more or less alteration to limonite. The outlines of the quartz grains are, as a rule, irregular, but angular rather than curved. Their substance is fresh, and shows few inclusions. The feldspar is largely in the form of lath-shaped individuals. It is likewise fresh and without inclusions or zonal structure. Twinning, after either the Carlsbad or albite law, is almost nowhere observable. The feldspars are, as a rule, fresh, simple individuals of sanidin.

An analysis of the rock by Mr. H. W. Nichols gave the following results:

Analysis of Rhyolite, Liparose, Cerro Mercado. Mus. No. E 8192.

SiO_2	73.92
Al_2O_3	12.38
Fe_2O_3	1.62
FeO	0.56
MgO	0.27
CaO	0.33
Na_2O	3.49
K_2O	5.39
H_2O	1.69
	99.65

Sp. Gr. = 2.420

From this the norm calculated in the three ways mentioned on page 205 is as follows:

	Quantitative composition.	Composition as affected by kaolinite and limonite.	Composition of unaltered rock.
Quartz	31.68	31.20	30.30
Orthoclase	31.69	31.69	31.69
Albite	29.34	29.34	31.27
Anorthite	1.39	1.39	1.47
Kaolinite	....	1.03	....
Corundum	.41	....	....
Hypersthene	1.62	1.62	1.62
Magnetite	.23	.23	.23
Hematite	1.46	....	1.46
Limonite	....	1.71	....
Water	1.69	1.30	1.30
	99.51	99.51	99.34

In either case the rock belongs to Class 1, Persalane, Order 4, Brittanare, Rang 1, Peralkalic and Subrang 3, Sodipotassic, Liparose. The composition, as above expressed, agrees well with that seen under the microscope, except in the quantity of albite, little of which can be definitely distinguished. In fact, it would seem to be doubtful whether the method of calculation advised by the authors of the quantitative classification by which all soda is assigned to albite is likely to give a correct result, since it seems to ignore the fact that nearly all orthoclase contains soda, often in considerable quantity.

The hand specimen collected to illustrate the rock nearer the mountain (Mus. No. E 8182), has a general chocolate-brown color and compact texture. Colorless transparent phenocrysts are scattered through it abundantly. These are generally lath-shaped, and show shining cleavage surfaces. Their average length is 2 mm. and their width 1 mm. Their hardness is 6, which property, together with their cleavage, marks them as sanidin. Occasionally similar individuals occur of larger size and less regular in shape, one of which noted has a diameter of 5 mm. The feldspars are the only minerals readily recognizable with the naked eye. Quartz is practically absent, so that the rock in this respect differs noticeably from that just described. A narrow vein of quartz scarcely a millimeter in width, in one place slightly open and lined with drusy quartz, ramifies through the specimen. Such a vein is obviously of secondary origin. Under the microscope the ground mass appears in general glassy in character, in places partially devitrified, so as to give a minutely granular appearance in polarized light. It is heavily impregnated with a reddish, opaque to translucent dust, the particles of which lack definite form. This dust is probably included iron oxide in the form of hematite, and to it the chocolate-brown color of the rock, as seen megascopically, is due. That the rock is impregnated by hematite is further shown by the fact that when a fragment is heated it turns black and becomes magnetic. Slender veins of the same hematitic character run here and there through the mass. This impregnation by hematite is confined to the ground mass, the feldspars being largely free from inclusions. Angular outlines characterize the feldspars. Cleavage lines are not prominent, and the crystals do not exhibit zonal structure. They are generally fresh and free from inclusions. As compared with the rock previously described, plagioclase is more abundant. Many individuals show polysynthetic twinning, and there are numerous intergrowths of sanidin and plagioclase. The only femic mineral of importance visible in thin section is hypersthene, which occurs in the form of coarse grains of a yellowish brown color. It is usually closely associated with the feldspars, and often is included by them. The grains lack crystal outline, and seem to have been absorbed to some extent. They have high index of refraction and little or no pleochroism.

An analysis of the rock, by Mr. H. W. Nichols, gave the following results:

Analysis of Rhyolite, Dellenose, Cerro Mercado, Mus. No. E 8182.

SiO_2	66.32
Al_2O_3	15.06
Fe_2O_3	4.59
FeO	0.53
MnO	Trace
CaO	1.63
MgO	0.86
K_2O	6.82
Na_2O	1.32
H_2O	1.28
P_2O_5	0.18
S	0.05
Sb	0.14
PbO	0.09
CuO	0.03
ZnO	0.27
CoO	0.15
BeO	None
ZrO	None
TiO_2	Trace
Cr_2O_3	None
	99.32

Sp. Gr. = 2.487

From this the norm calculated in the three ways described on page 205, is as follows:

	Quantitative composition.	Composition as affected by kaolinite and limonite.	Composition of unaltered rock.
Quartz	28.26	24.80	21.67
Orthoclase	40.03	40.03	40.03
Albite	11.00	11.00	17.78
Anorthite	7.23	7.23	11.70
Corundum	2.96	....	....
Kaolinite	....	7.46	....
Hypersthene	3.02	3.02	3.02
Hematite	4.59	3.17	4.59
Limonite	....	1.66	....
Apatite	0.31	0.31	0.31
Water	1.28	....	....
Stibnite	0.19	0.19	0.19
Other oxides	0.54	0.54	0.54
	99.41	99.41	99.83

In either case the rock belongs to Class 1, Persalane, Order 4, Brittanare, Rang 2, Domalkalic, and Subrang 2, Dopotassic, Dellenose.

As compared with the rock described just preceding this differs chiefly in being more highly feldspathic, less acidic, and in containing more potash and ferric oxide. Its content of an appreciable quantity of antimony, lead, copper, zinc, and cobalt is also a remarkable feature. Whether the presence of these indicates an impregnation of the rock subsequent to its eruption, by waters containing these metals in solution, or whether they were original constituents of the magma, it seems impossible to say.

The age of the rocks to which the series of the Cerro Mercado belongs has been stated by Ordoñez to be late Tertiary,* and this opinion is generally concurred in, since there is no doubt that the main elevation of the Mexican Cordilleras took place in Eocene time, and that the eruption of the rhyolites about Durango was subsequent to this.

Being formed, therefore, in so late a period in geological history, the Cerro Mercado is unique as compared with other extensive iron deposits, such as those of Sweden and the Lake Superior region in North America. These, as is well known, are considered pre-Cambrian in age. De Launay has called attention to this latter fact,† as indicating that these deposits owe their origin to conditions prevailing in the earlier stages of the earth's history, when the crust was relatively thin. He concludes that the processes of their formation must have been deep-seated in character, because the products

---

*Bol. Inst. Geol. de Mexico, Num. 14, p. 65, *et seq.*

†Annales des Mines, 10me ser. Tome IV. p. 50.

have been brought to light only after long ages of erosion. If the Cerro Mercado, however, owes its origin to similar processes, it is evident that these are capable of operating in the later periods of the earth's history as well as the earlier.

The association at the Cerro Mercado of a large amount of iron oxide with relatively acid rocks is another unusual feature, since for the most part other iron deposits of probable igneous origin, such as those of the Urals and of Sweden, have basic rocks in association. The most important exception to this rule seems to be the deposit of Kirunavara, Sweden, in connection with which De Launay notes acid porphyries (quartz keratophyres), as occurring in considerable quantity.*

The question of the origin of the Cerro Mercado is not one which has been heretofore extensively discussed. Weidner considered it to represent the product of a volcanic eruption,† while Burkart regarded it as intrusive.‡ Weidner's view of the volcanic origin was based chiefly on the tuffs found in the vicinity and the absence of evidences of contact metamorphism. Chrustschoff§ considered the process eruptive and that the stratigraphy showed that the iron oxide at two points broke through the porphyry and spread out over the latter. On account of certain peculiarities in the appearance of some of the ore lumps, however, he was of the opinion that the outpoured mass was, at the time of its eruption, in a "hot-fluid, watery" condition. Ordoñez believed that the iron oxide was of a later origin than the surrounding rocks and filled a fissure formed in them.‖ The supposed steps of the process are not indicated in any further detail by this author, however. With the exception of Ordoñez it will be seen that the general trend of opinion has been in favor of an eruptive origin for the mass. Among earlier writers, however, the possibilities of sedimentary origin of iron deposits were less generally accepted than now.

In favor of an igneous origin for the iron oxide of the Cerro Mercado, the wholly igneous character of the accompanying rocks, the integrity, continuity, and extent of the iron oxide, and its unstratified, columnar structure, are the factors which in the view of the present writer weigh most strongly.

If it be of igneous origin, however, it is difficult to conceive of the steps of the process by which it was formed. It seems necessary to suppose that either, on the one hand, it welled up from below and filled a fissure, or that, on the other hand, a separation took place into an acidic and basic portion while the magma was still in a fused condition. If the former action took place one would expect to find evidences of contact metamorphism such as have not yet been observed. The latter supposition seems equally untenable, however, owing to the difficulty of conceiving of the separation of a magma into proportions so acidic on the one hand and so basic on the other. That masses of magnetite of considerable bulk may be of eruptive origin seems to be generally conceded, several occurrences being usually so explained. In most of these cases, however, the accompanying rocks are basic in character, so that it is not difficult to conceive of the separation of iron from such a magma. As already noted, however, the rocks accompanying the iron oxide at the Cerro Mercado are acidic in character.

---

*Op. cit., p. 75.

†Op. cit.

‡Op. cit.

§Op. cit.

‖Bol. Inst. Geol. de Mexico, Num. 16, p. 11.

At many points on the mountain the line of demarkation between eruptive rock and iron oxide is sharp and distinct, while at other points a gradation is traceable. Thus Rangel says,* "at the base is seen an enormous bank of compact rhyolite; a little higher up appears a deposit of fragments of rhyolite; higher up yet the fragments of rhyolite are covered on some of their sides with ferruginous material crystallized in small octahedrons and mixed with pieces of the mineral. The proportion of mineral increases as the height until it constitutes exclusively the material."

Witherbee also describes† "large lumps of what appears to be solid iron ore, which, upon breaking, prove to be only pieces of *cantera* covered with a superficial coating of iron oxide, often highly crystalline, and only from 0.25 to 0.5 in. thick, as though the rock had been immersed in molten iron oxide." Moreover, the studies made in the preceding pages show a change in the substance of the rock itself in approaching the mountain. It becomes more basic, though not highly so, and shows a gradual increase in content of iron. Do such phenomena as these represent primary or secondary changes? If primary, is the iron oxide younger than the undoubted eruptives? If so, has it flowed over them, or has the separation been of a magmatic nature? If secondary, can the phenomena be referred to the action of infiltrating waters? Such are some of the questions regarding the origin of the mass of iron oxide which remain yet to be answered. Metasomatic processes, to which, for several reasons, the origin of the iron might be ascribed, should, it would seem, more extensively impregnate the adjoining rocks than has been the case.

---

*Translation by Kirby Thomas, Mining World, Feb. 12, 1904.

†Trans. Am. Inst. Min. Eng., Vol. XXXII., p. 156.

Again the derivation can hardly be ascribed to ferrous silicates of the adjoining rocks as in the case of the Lake Superior ores, since such silicates seem to be practically lacking in the associated rocks here. On the whole, therefore, the relation, either in time or manner of origin, between the associated eruptive rock and the iron oxide, and the origin of the iron oxide itself, seem as yet difficult to determine with certainty.

FIELD COLUMBIAN MUSEUM
PUBLICATION 94.
GEOLOGICAL SERIES. VOL. II, NO. 6.

STRUCTURE AND RELATIONSHIPS OF OPISTHOCŒLIAN DINOSAURS.

PART II.

THE BRACHIOSAURIDÆ

BY

ELMER S. RIGGS, A.M.
Assistant Curator, Division of Paleontology.

OLIVER CUMMINGS FARRINGTON, PH. D.
Curator of Geology.

CHICAGO, U. S. A.
September 1, 1904

STRUCTURE AND RELATIONSHIPS OF OPISTHOCŒLIAN DINOSAURS.

PART II.

THE BRACHIOSAURIDÆ.

BY E. S. RIGGS.

The genus *Brachiosaurus* was recently described* by the writer from the humerus, femur, coracoid, and such parts of the sacrum and vertebral centra as could be seen before the specimen had been removed from the matrix. During the past winter the sacral and presacral vertebræ, which had been badly damaged by weathering, have been reconstructed with great care and patience by Messrs. J. B. Abbott and C. T. Kline. As these parts have one after another been worked out, the unusual character of this animal, which was first indicated by the extraordinary proportions of the humerus, has become more and more evident. So different is its structure from that of other members of the Opisthocœlia that the writer feels justified in placing it in a new family. The Brachiosauridæ is, therefore, proposed as a family group, to include this genus together with the smaller and more primitive form recently described by Hatcher under the name *Haplocanthosaurus*.

The family characters so far observed are: *Humerus as long as femur; neural spines of vertebræ simple; dorsal vertebræ more than ten.* Other characters equally distinctive will doubtless develop as these animals become better known. The following key will aid in determining members of this group:

Opisthocœlian dinosaurs with fore leg longer than hind; vertebral spines simple throughout; number of dorsal vertebræ more than ten: Family Brachiosauridæ.

(*a*) *Size medium; dorsal vertebræ fourteen; centra not elongate; neural arch unusually elevated, diapophyses directed obliquely upward and outward, hyposphene-hypantrum articulation moderately developed: Genus Haplocanthosaurus.*

(*b*) *Size large; neural arches not unusually elevated, spines increasing in length from sacrum to mid-dorsal region, hyposphene-hypantrum*

---

* Am. Jour. Sci., Ser. 4, vol. 15, p. 299.

articulation unusually developed, centra of dorsal vertebræ elongate: Genus Brachiosaurus.

The type specimen of *Brachiosaurus* as now prepared for exhibition, consists of the sacrum, seven presacral and two anterior caudal vertebræ, the right humerus, coracoid, ilium, and femur, and a number of ribs more or less complete. It was collected by the Museum paleontological expedition of 1900 from the Grand River valley of western Colorado. (Pate LXXI.) When found, the vertebral column was lying with spines downward and the vertebræ were but little displaced from their normal relations. The ventral surface of the sacrum, the ilium, and the anterior caudal vertebræ were exposed, and had suffered more or less from weathering.

At the seventh presacral vertebra the thin clay stratum in which the specimen was imbedded "pinched out," and was replaced by a massive layer of sandstone with coarse sand and pebbles at the base. This, together with the uniform displacement of the ribs, humerus, and coracoid to the left and the presence of an isolated ilium of *Diplodocus*, which had the appearance of having been drifted up against the broken vertebral series, indicated that the anterior portion of the skeleton had been carried away by the invasion of a water-current after the specimen had been partially covered with sediments.

The humerus and coracoid were displaced some ten feet to the left, and when found the distal end of the former was exposed at the surface, broken and displaced. When the fragments had been gathered up and fitted to the portion still in the matrix the bone measured almost seven feet in length. This length so much exceeded that of any humerus previously known, that the writer at the time believed it to be a crushed and distorted femur. Had it not been for the unusual size of the ribs found associated with it, the specimen would have been discarded as an Apatosaur, too poorly preserved to be of value.

The conclusion that the bone in question was a distorted femur was given additional weight by the discovery soon after of a well-preserved femur of almost identical length, associated with the ilium and sacrum. But later, when the two leg bones were removed from the matrix and carefully compared in the laboratory, the identity of the humerus was at once established by the structure of the head as well as by the clearly defined deltoid area from which the deltoid crest had been broken away and lost. From figures 3 and 4, Plate LXXIV, the characteristic structure of the opisthocœlian humerus will at once be recognized.

DORSAL VERTEBRÆ.

The seven dorsal vertebræ preserved in the specimen were found in a series, and but little displaced from their relative positions. The centra and transverse processes are considerably distorted by the compression to which they have been subjected. These distortions have been corrected in the specimen as far as was practicable, but no effort has been made to further correct them in the drawings. (Plate LXXII.) The vertebræ are distinguished by the lightly constructed and elongate centrum with its large lateral cavity, and by the single neural spines, short in the posterior members of the series, but becoming more and more elongate anteriorly. Equally distinctive is the unusual development of the hyposphene-hypantrum articulation. The whole structure suggests lightness and flexibility attained with an evident sacrifice of that strength which is everywhere apparent in the unwieldy *Apatosaurus*.

The number of vertebræ in the dorsal series cannot, of course, be determined from this specimen. Reasoning from certain similarities between this genus and *Haplocanthosaurus*, in which the number has been determined as fourteen,* we may expect a more numerous series than characterizes *Apatosaurus* and *Diplodocus*. As this number must for the present remain conjectural, however, the vertebræ will be referred to as presacral and numbered from the sacrum forward.

The first presacral vertebra may be distinguished, as in all opisthocœlians so far as the writer has observed, by the massive postzygapophyses which overhang the posterior end of the centrum, by the low stout spine and the short centrum† with small lateral cavities or pleurantra. From this point forward, both the centra and spines rapidly elongate, the diapophyses become more and more expanded, but, contrary to all that might be expected, the zygapophyses become reduced almost to insignificance.

The *centrum* in the dorsal vertebræ is opisthocœlous in type, but less pronouncedly so in the anterior members of the series than is common in the mid-dorsal region of most forms. In the first presacral the centrum is similar in length to that of *Apatosaurus*, but in the preceding vertebræ it rapidly increases in length. The pleurantrum is of moderate size; the anterior end of the centrum is truncate, with a slight convexity above the middle: the posterior end, now badly distorted, was doubtless uniformly concave. The second centrum takes on a more typical opisthocœlous outline. From this point forward the centra increase slightly in length, the pleuracœle enlarges, and the general structure displays even greater lightness. A cross-section shows an internal arrangement very similar to that of *Apatosaurus* (*Brontosaurus*) as figured by Marsh.

---

* Memoirs of the Carnegie Museum, vol. 2, No. 1.

† In the preliminary description of this genus the writer, estimating from the specimens still in the matrix, characterized the posterior dorsal centra as longer than wide. Closer examination shows that this is not true of the last dorsal.

However, the lateral cavities are larger, and the peripheral walls thinner than have been observed by the writer in that genus. The median septum is so fragile as to be lost entirely in some of the vertebræ.

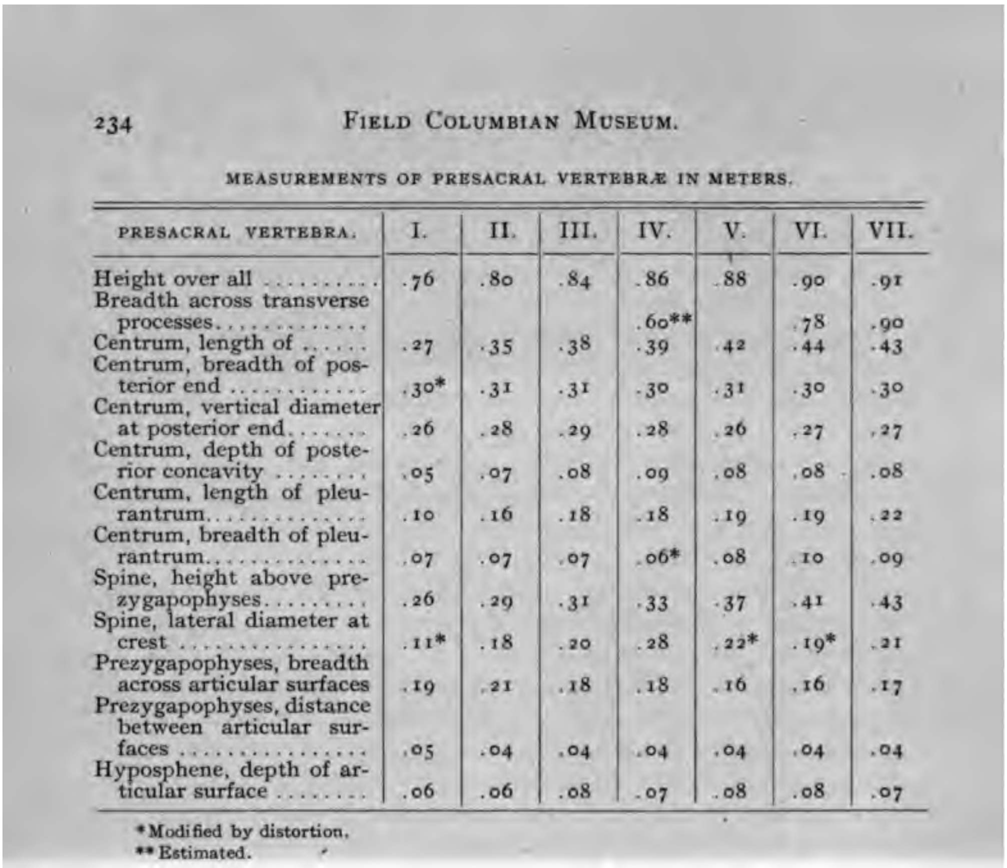
The *neural arch* is unusually slight in this genus. Its posterior surface is narrow and rounded; anteriorly it is produced into two laterally directed ridges which descend from the base of the prezygapophyses to the anterior rim of the centrum. Inclosed by these ridges and by the buttresses supporting the prezygapophyses is a deep fossa, into the lower margin of which the neural foramen opens.

The *transverse processes* in presacrals I to III and in V are broken and lost. In those vertebræ in which they are preserved, these processes have been too much distorted to admit of their direction being determined with certainty. In the posterior members of the series they were evidently much reduced. In IV a single transverse process is preserved which is little more conspicuous than the tubercular facet. In VI and VII these processes rapidly increase in length. They arise from four roots very much as do those of the posterior dorsals in *Apatosaurus*. They are broad at the base antero-posteriorly, rugose on the anterior margin, and recurved at the distal end.

The *capitular facets* for the rib attachment are borne high above the centrum throughout the present series. In presacrals I and II there is little evidence as to their position, but in III a well-developed facet is preserved. From this point forward the facets are borne by the lateral surface of the prezygapophyses as well as the anterior margin of the transverse process, and are supported by a buttress descending to the anterior margin of the neural arch. The zygapophyses, together with the hyposphene-hypantrum articulation constitute one of the distinguishing features of the vertebræ of this genus. Throughout the dorsal series, so far as known, the zygapophyses are narrow and placed close to the median line. There is no evidence of dichotomy in the anterior dorsal region as observed in *Apatosaurus*, *Camarasaurus*, *Morosaurus*, and *Diplodocus*. The weakness in the zygapophyses is compensated by the strength of the hyposphene-hypantrum articulation. The articular surfaces of the former are directed horizontally. The mesial surface of the prezygapophysis curves rapidly downward and is continuous with the vertical articular surface of the hyposphene. Similarly the articular surface of the postzygapophysis is continuous with that of the hypantrum. The two form a firmly interlocking joint capable of resisting lateral strain. The hypantrum is also slightly expanded inferiorly so as to prevent a downward displacement of the prezygapophyses.

The *prezygapophyses* are supported by a single pair of buttresses, which also form the anterior margin of the neural arch, and by the anterior plate of the transverse process. The postzygapophyses are supported from above by a pair of stout buttresses which descend from the postero-lateral margin of the spine; laterally they are supported by the posterior root of the transverse process and inferiorly by a pair of buttresses arising from the posterior margin of the neural arch and attaching to the anterior surface of the hypantrum. In the sixth and seventh presacrals this support is strengthened by passing to the inferior surface of the hypantrum.

The *neural spines* in this genus are single and median so far as known, and there is no reason to doubt that they continue so throughout the dorsal series. Unlike those of any other known members of the Opisthocœlia, the spines are short in the first presacrals, and become more and more elongate as far as the middle thoracic region. They are made up of the usual median plate expanded at the crest into a rugose knob and roughened on the anterior and posterior margins for the attachment of interspinous ligaments. They are flanked at the anterior and posterior margins respectively by a pair of greater and lesser lateral plates. The posterior plates arise from the superior root of the prezygapophyses, pass upward along the lateral border of the median plate near the posterior margin, and form a stout lateral support to the crest. The anterior lateral plates arise similarly from the base of the prezygapophyses and strengthen the anterior border of the median plate. In presacral I the spine is low, massive, and strongly reinforced by buttresses arising from the postzygapophyses. In II it is noticeably higher and less firmly braced. In IV and V the base of the spine becomes broadened anterio-posteriorly by the diverging roots of the lateral plates. A lateral vacuity appears between the posterior and inferior roots of the transverse process and the base of the postero-lateral spinous plate. In VI and VII the spine becomes more elongate and somewhat more slender.



MEASUREMENTS OF PRESACRAL VERTEBRÆ IN METERS.

PRESACRAL VERTEBRA.	I.	II.	III.	IV.	V.	VI.	VII.
Height over all	.76	.80	.84	.86	.88	.90	.91
Breadth across transverse processes.............				.60**		.78	.90
Centrum, length of	.27	.35	.38	.39	.42	.44	.43
Centrum, breadth of posterior end	.30*	.31	.31	.30	.31	.30	.30
Centrum, vertical diameter at posterior end.......	.26	.28	.29	.28	.26	.27	.27
Centrum, depth of posterior concavity	.05	.07	.08	.09	.08	.08	.08
Centrum, length of pleurantrum..............	.10	.16	.18	.18	.19	.19	.22
Centrum, breadth of pleurantrum..............	.07	.07	.07	.06*	.08	.10	.09
Spine, height above prezygapophyses.........	.26	.29	.31	.33	.37	.41	.43
Spine, lateral diameter at crest	.11*	.18	.20	.28	.22*	.19*	.21
Prezygapophyses, breadth across articular surfaces	.19	.21	.18	.18	.16	.16	.17
Prezygapophyses, distance between articular surfaces	.05	.04	.04	.04	.04	.04	.04
Hyposphene, depth of articular surface	.06	.06	.08	.07	.08	.08	.07

*Modified by distortion.
**Estimated.

SACRUM.

The sacrum of *Brachiosaurus* is at once distinguished from that of the other large opisthocœlian dinosaurs by its unusual breadth across the sacral ribs as compared with its length and the height of its component vertebræ. (Plate LXXIII.) The specimen under consideration has been damaged somewhat by compression, but more seriously by later exposure to weathering at the surface. As a result, the neural arches of sacrals II–IV inclusive were too badly damaged to be restored; and with them the centra above the lateral cavities. With these exceptions their structure can be determined with certainty.

The sacrum is made up of five ilium-supporting vertebræ instead of four, as originally described,* all of which are firmly coössified by their centra and the distal ends of their sacral ribs. Sacrals I to IV are coalesced by their zygapophyses and the base of their diapophyses, and sacrals II and III by their spines. As in the typical opisthocœlian sacrum† the ribs of sacrals II, III, and IV enter into the composition of the sacricostal yoke and may be regarded as comprising the primary sacrum. The dorso-sacral is highly specialized, but its support of the acetabulum is a secondary function. The caudo-sacral is functional as an ilium-supporting vertebra, though its caudal affinities are still clearly marked.

---

*Am. Jour. Sci., 4th Ser., vol. 15, p. 303.

†This publication, GEO. SER., vol. ii, No. 4, p. 180.

The *centrum* of sacral I is somewhat shorter than that of the last dorsal, and is irregularly convex on the anterior end. The pleurantral foramina are almost closed by the expanded sacral ribs. The centrum of sacral II is similar in length to that of I, but is laterally expanded to meet the unusual development of its sacral rib. There is no evidence of a pleurantrum. The centra of III and IV are less expanded laterally, and bear traces of the pleurantral foramen. That of V bears no trace of the lateral cavities. Its posterior end may have been convex above and concave below, as is the typical structure, although this feature cannot be determined with certainty.

The *sacral rib* in I is developed into a broad, winglike appendage, whose primary elements can scarcely be traced. It arises from the upper half of the centrum anterior to the much-reduced pleurantrum and from the lateral surface of the neural arch. The capitular portion passes backward, joins the rib of sacral II, and articulates with the mesial surface of the greater peduncle. The tubercular element is fused with the distal end of the diapophyses so that it is impossible to determine where the one ends and the other begins. It is probable, however, that the tubercular portion of the rib is represented by the rugose end only. It attaches to the crest of the ilium above and in front of the base of the greater peduncle.

The second pair of sacral ribs are by far the strongest of the series. The proximal ends are greatly expanded and attach to the whole lateral surface of centrum II as well as to the posterior half of centrum I. The shaft is constricted at the middle, and the distal end is expanded to enter into the composition of the sacricostal yoke. The third pair of ribs are much reduced in size. They arise from the anterior half of centrum III in common with the posterior margin of the second pair. The shaft is slight, but the distal end is expanded to form the middle section of the yoke. The fourth pair arise from the anterior two-thirds of the centrum. From the superior margins of ribs II, III, and IV broad plates arise to connect with the corresponding diapophyses. The fifth pair of sacral ribs arise from the mid-lateral surface of the centrum, and passing diagonally forward, unite with the distal ends of the fourth pair in supporting the lesser peduncle of the ilium. These bear traces of the primary caudal structure although they are modified as ilium-supporting elements.

The *diapophyses*, like the sacral ribs, are remarkable for their unusual length and slenderness. The first pair arise from the lateral surface of the spine and the stout prezygapophyses. Their distal ends unite with the sacral ribs in forming the great lateral plates. The second and third pairs arise in common from the fused spines of sacrals II and III. Distally they diverge to unite with the iliac crest. The fourth pair arise independently; they are directed diagonally backward and attach to the border of the ilium above the lesser peduncle. Midway between the base of the diapophyses and the attachment with the ilium there is a marked rugosity which suggests that the diapophysis may terminate at that point and the distal portion be made up of the tubercular portion of the rib. This could be determined only from the study of a very young specimen.

The *sacral spines* are remarkably short and blunt. In structure they are made up of a thickened median plate expanded at the crest to form a blunt knob, and flanked in the anterior three by a slight pair of lateral spinous plates. The first is free, but stands close to the second. In structure it resembles the posterior dorsal, though its lateral plates have almost disappeared. The second and third spines are so firmly united as to show no trace of the line of fusion. Their lateral plates arise from the middle of their respective surfaces. The fourth and fifth take on the caudal type of structure, which consists of a median plate expanded into a simple knob at the crest. The fourth stands quite close to the third; the fifth is isolated. All have marked rugosities on the anterior and posterior margins for the interspinous ligaments.

MEASUREMENTS OF SACRUM.

	M.
Length of five sacral centra	.95
Breadth across second pair of sacral ribs	1.05
Breadth across fifth pair of sacral ribs	.98
Height of first sacral vertebra	.64*
Height of third sacral vertebra	.60*
Height of fifth sacral vertebra	.53*
Length of centrum I	.19
Length of centrum II	.18
Length of centrum III	.15
Length of centrum IV	.22
Length of centrum V	.21

* Dimension modified by distortion.

CAUDAL VERTEBRÆ.

Two anterior caudal vertebræ were found in close apposition with the posterior end of the sacrum. The first has been so distorted in a diagonal direction that the structure of its centrum and zygapophyses can scarcely be determined. The second (Figs. 1 and 2, Plate LXXV) has suffered less from distortion, and is otherwise fairly well preserved. The centra are in general amphicœlous. The anterior end of the first is concave in its lower half, but is so badly distorted that it does not show whether or not it had the characteristic convexity usually found in the upper half of the first centrum. The posterior end is slightly concave, a feature which the crushing has tended to lessen. In the second caudal the anterior end is uniformly concave, the posterior end slightly more so. There is no trace of the lateral cavities found in almost all the opisthocœlians. It cannot be determined whether or not these vertebræ were chevron-bearing.

The *neural arches* are massive, broad on the anterior surface, but drawn to a rounded angle about the posterior opening of the neural foramen. Laterally there are traces of a slight ridge leading downward from the prezygapophyses to the base of the transverse process.

The *zygapophyses* are slight for a vertebra of such dimensions; the anterior pair has been pushed upward by compressure. The articular facets normally face inward and slightly upward. The posterior pair in the second caudal bears distinct evidence of a hyposphene.

The *neural spines* are characteristically simple. They are laterally compressed at the base and expanded at the crest into a roughened knob. The anterior and posterior margins bear the strong rugosities for interspinous ligamental attachments which persist throughout the vertebral series.

The *caudal ribs* are equally simple. The capitular element is represented by a stout process arising from the lateral surface of the centrum above the middle. It is vertically compressed and apparently expanded into a rounded end. No trace of the tubercular element is to be seen.

MEASUREMENTS OF CAUDAL VERTEBRÆ.

	Caudal I.	Caudal II.
Height over all	.61*	.59
Centrum, length of	.16	.15
Depth of anterior end	.28*	.29
Breadth of anterior end	.33	.31
Breadth across transverse processes	.56*	.48
Spine, height above zygapophyses	.18	.17
Antero-posterior diameter	.10	.10
Lateral diameter at crest	.11	.09

*Dimension modified by distortion.

The *ilia* are represented by the right bone, which has lost its greater peduncle, but is otherwise quite well preserved, and a badly weathered left, which, fortunately, has the greater peduncle preserved. The right bone has been modified by a distortion which has depressed the whole posterior half, straightened the superior border, distorted the acetabulum, and reduced the depth in the supra-acetabular region. It is figured from a lateral view without correction, other than the restoration of the greater peduncle from a comparison with that of the left. (Fig. 3, Plate LXXV.)

The important feature of the ilium is the unusual development of the pre-acetabular portion. The greater peduncle is near the middle; the anterior half is expanded into a broad but rather thin plate, most of which stands anterior to the attachment of the first sacral rib. At the point of greatest eminence the crest is thickened for the attachment of the first diapophysis. The anterior border is much more rounded than it is in any of the other large dinosaurs. At the anterio-inferior angle the border is quite thick and roughened for muscular attachment. This roughening continues one-third of the way from the angle to the point of attachment for the first sacral diapophysis, where it disappears and the border becomes thin and rounded. The crest continues very thin to a point over the middle of the acetabulum, where it again becomes stronger and rugose. This continues to the posterior angle, which is much thickened, and offers the usual broad surface for the origin of lateral caudal muscles.

The acetabulum is distorted by the depression of its arch. It presents to the head of the femur a broad and rounded surface, which terminates at either end in the peduncles. Its superior surface takes the form of an arch which juts far beyond the iliac wall on the mesial side, and presents a concave surface for the support of the sacricostal yoke. The attachment for the first diapophysis is a triangular fossa bounded by two ridges which descend from the crest and converge at a point seven or eight inches below. From this point a rounded ridge passes obliquely downward and backward to the base of the greater peduncle. The points of attachment of the second and third diapophyses are very slight; no trace of a fourth appears. The fifth has a strong attachment at the thickened crest above the lesser peduncle. The plates connecting the diapophyses with the sacral ribs do not attach to the iliac wall as in *Apatosaurus*.

THORACIC RIBS.

The unusual length of the ribs, as well as the breadth of the head and tubercle and the strength of the shaft, bears evidence of the immense thorax of this animal. One of the more slender ribs from the mid-thoracic region measures fully nine feet (2.745 m.) in length. Another has a shaft eight inches (.204 m.) in breadth. The head and tubercle are almost equally developed and widely separated to give the firm attachments rendered necessary by the great length of the ribs. (Fig. 5, Plate LXXV.) In some instances the attachment is strengthened by a second tubercle on the inferior surface of the head similar to that figured by Marsh on the cervical vertebræ of *Apatosaurus*. The anterior surface of the shaft below the head is perforated by a large foramen which leads to an internal cavity. On account of the elevation of the capitular facet on the vertebræ, the head and tubercle are borne almost on a level. By reason of this the flattened surface of the proximal end passes insensibly into the lateral surface of the shaft without that twist common to the ribs in animals of this group.

LEG BONES.

The *humerus* is somewhat crushed antero-posteriorly and twisted so that the head and distal end are brought into the same plane. The surface of the distal end has flaked away in the process of weathering to a firm chalcedony core. (Fig. 1.) In relative slenderness the humerus is approached more nearly by that of *Diplodocus* than that of any other well-known American dinosaur. The head is considerably expanded, forming a rounded prominence especially conspicuous on the posterior surface. The great tuberosity is stout and rugose; its proximal surface meets the lateral margin of the shaft in a pronounced angle. This angle is not produced posteriorly to inclose a fossa as in *Morosaurus*. The inner border below the head is drawn out into a rather thin margin, though roughened for muscular attachment. The deltoid crest is partially broken away, but was evidently quite prominent. (Fig. 4, Plate LXXIV.) Its base forms with the anterior surface of the shaft a broad and shallow concavity. Midway between the deltoid crest and the great tuberosity is a second rugose surface evidently for the insertion of other shoulder muscles. The ectepicondylar ridge is entirely lost, owing to the weathering to which the distal end has been subjected. The direction of the bone fibres on the lateral margin indicates that it may have been quite prominent. All traces of rugosity have likewise disappeared from the distal end, indicating that the humerus was probably some inches longer than it now stands.

The *coracoid* is a larger, but less massive, bone than that of *Apatosaurus*. (Fig. 4, Plate LXXV.) It is elongate antero-posteriorly, rounded on its inferior margin, and straight at the scapular articulation. The glenoid articular surface is directed outward as well as backward, a feature observed in no other opisthocœlian genus. The postero-inferior surface is thick and rugose for epicoracoidal attachment near the glenoid cavity, from which it is separated by a narrow notch only. The posterior border becomes gradually thinner, and its rugose character disappears midway between the glenoid cavity and the anterior scapular angle. The emargination noticeable in the specimen at this point is due to crushing from contact with the head of the humerus while in the matrix.

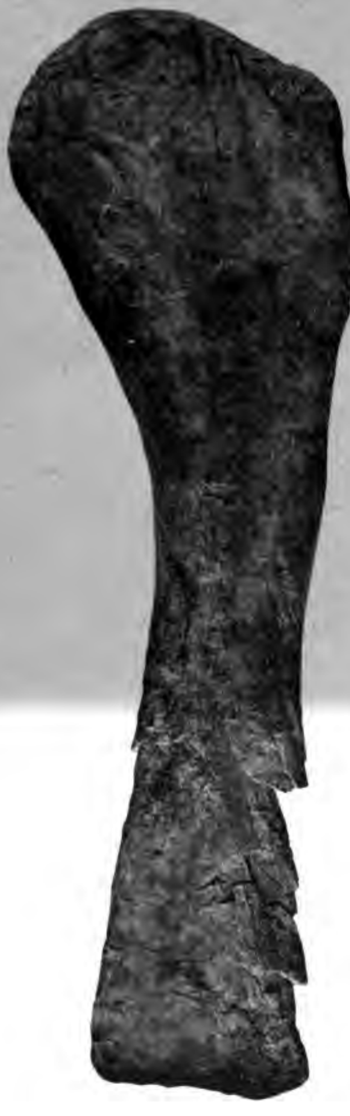


Fig. 1. Posterior view of right humerus of *Brachiosaurus altithorax*. $\frac{1}{14}$ natural size.

The *femur* is well preserved, though somewhat compressed antero-posteriorly. (Figs. 1 and 2, Plate LXXIV.) Regardless of its great length, this bone is almost as stout in the shaft as that of *Apatosaurus*, though the articular ends are proportionally less expanded. The lateral surface of the shaft has a prominent convexity one-fourth of its entire length below the great trochanter. A marked rugosity, probably for the insertion of one of the gluteal muscles, extends downward from the great trochanter to this point. As in all opisthocœlians the fourth trochanter forms a rugose prominence on the posterior internal margin of the shaft above the middle.

MEASUREMENTS OF THE LEG BONES.	M.
Humerus, length of parallel to axis	2.04
Greatest breadth of proximal end	.65
Thickness of head antero-posteriorly	.28
Least breadth of middle shaft	.24
Distance from angle of great tuberosity to upper margin of deltoid crest	.51
Femur, length parallel to axis	2.03
Breadth of head and great trochanter	.59
Breadth of shaft at fourth trochanter	.43
Breadth at distal end	.58
Distance from head to upper margin of fourth trochanter	.78
Coracoid, greatest breadth	.87
Inferior border to scalpular margin	.54
Glenoid margin to foramen	.34
Ilium, greatest length	1.24
Breadth of preacetabular plate	.53
Base of great peduncle to anterior angle	.40
Length of great peduncle	
Depth over acetabulum (estimated)	.45
Lateral breadth of acetabular wall	.16
Thickness of plate at antero-inferior angle	.08
Thickness of crest above great peduncle	.025
Thickness of posterior angle	.12

RELATIONSHIPS.

In proposing the genus *Brachiosaurus* from the characters presented by the leg bones and sacral centra of this specimen, the writer had some doubt as to the possible relations with the imperfectly described genus *Camarasaurus*. However, a recent examination, through the courtesy of Dr. Osborn, of the type specimen as it is being prepared for exhibition in the American Museum, at once set at rest all such doubts. The massive structure of the vertebræ and the distinctly Morosaur-like spines of that genus have nothing in common with the slenderly constructed and elongate centrum and the single median spines of *Brachiosaurus*. Relationship with the tall and slender posterior dorsal vertebra which constitutes the type of *Amphicœlias* is equally impossible.

Of all the American opisthocœlia the only known form which may be regarded as closely related to this genus is *Haplocantho-*

saurus, recently described* by Hatcher. These two genera display certain structural affinities common to no other North American group. The most important of these are: (1) the single median spines which persist throughout the vertebral column in the above-named genus and which appear to have been equally persistent in *Brachiosaurus;* (2) the unusual breadth of the sacrum in comparison with its length and the height of its component vertebræ; (3) the simple structure of the anterior caudal vertebræ; (4) the great expansion of the preacetabular portion of the ilium. In addition to these, are to be considered the presence of fourteen dorsal vertebræ as described by Hatcher in *Haplocanthosaurus*, and the unusual length of the humerus in *Brachiosaurus*. Recent developments with regard to the number of vertebræ in *Diplodocus*† and in *Apatosaurus*‡ might throw some doubt upon this point were it not that the genera under consideration evidently belong to a distinct phylogenetic line, and that Hatcher has made a strong case in favor of fourteen dorsal vertebræ in his genus. The vertebral formula in *Brachiosaurus* cannot, of course, be determined from the interrupted series preserved in the type specimen. It is most probable that the number will prove to be the same as in *Haplocanthosaurus*, although the elongation of the dorsal centra might suggest that a reduction had taken place in this form.

Of the two genera, it will be observed that *Haplocanthosaurus* is much the smaller and comparatively primitive, while *Brachiosaurus* is a long-limbed and highly specialized type. Points of generic difference are abundant. The first and most evident of these is one of size, which is well indicated by the comparative length of femora. That of *Haplocanthosaurus* measures about fifty inches, while in *Brachiosaurus* the same bone measures fully eighty. More important differences are to be found in the relative height of the neural arches, the development of the hyposphene-hypantrum articulation, and the length of the centra in the dorsal vertebræ.

In the smaller genus the vertebral pedicles are peculiarly attenuate, giving to the neural arch the extraordinary elevation pointed out by Hatcher, and to the neural canal the unusually great vertical diameter. In the larger and more highly specialized *Brachiosaurus* there is no evidence whatever of this characteristic. The pedicles are broad antero-posteriorly, narrow and rounded on the posterior margin instead of being produced into an angle, as in the smaller form, and the neural canal is but little deeper than wide.

---

* Memoirs of the Carnegie Museum, vol. ii, No. 1.

† Memoirs of the Carnegie Museum, vol. i, No. 1, p. 29.

‡ This publication, GEOL. SER., vol. ii, No. 4, p. 196.

It will be observed that in *Haplocanthosaurus* the zygapophyses are about as strong as those of *Morosaurus*, and extend a like distance from the median line. Their articular surfaces are plane and directed slightly upward as well as laterally. The hyposphene has a moderate development. In *Brachiosaurus*, on the other hand, there is a marked crowding together of the zygapophyses at the median line, especially in the mid-dorsal region, and an unusual development of the hyposphene-hypantrum articulation. The articular surfaces of the zygapophyses are directed laterally and are slightly curved, so that the postzygapophyses embrace the anterior pair. The centra of the dorsal vertebræ in the larger genus are, with the exception of the last, much more elongate and more thinly walled than in the smaller form. The sacral ribs also show a much higher degree of specialization. In *Haplocanthosaurus* they arise uniformly from the anterior end of the centra and show but little variation in strength throughout the series. In the larger animal, however, the second pair are greatly expanded, as has been described above, while the third pair are correspondingly reduced in size. There is also a much greater relative expansion of the thoracic cavity, as is shown by the comparative length of the anterior ribs.

The neural spines of *Brachiosaurus*, so far as preserved, present the same type of structure as do those of *Haplocanthosaurus*, but while those of the latter genus reach their greatest length at the third presacral and begin to diminish with the sixth, those of the former increase regularly to the seventh. There is also a more pronounced shortening of the neural spines and transverse processes of the anterior caudals in *Brachiosaurus*, indicating a reduction of the caudal series, consistent with the cephalad specialization of this form.

In most of the above noted differences, *Haplocanthosaurus* presents a more primitive structure, from which *Brachiosaurus* might well be derived. However, the elevation of the neural arches and the upward direction of the diapophyses in the smaller form present a degree of specialization which precludes this possibility. A very similar condition exists in *Stegosaurus*, probably as an adaptation to the support of its dermal armor. While it is hardly possible that such an armor could have existed in this form without having been preserved in one or the other of the two specimens described by Hatcher, the elongation may have resulted from a like muscular development, or it may be due to acquired aquatic habits, as such a tendency is found in certain cetaceans. To assume that the dorsal pedicles had attained such an elevation and were again reduced to the low, broad structure found in *Brachiosaurus*, would be inconsistent with all laws of organic development. We must, therefore, conclude that the two forms have arisen from a common ancestry, probably somewhere in the lowermost Jurassic, and that while the *Haplocanthosaurus* phylum remained in general conservative, it reached a high degree of specialization in this one particular. *Brachiosaurus*, on the other hand, is a somewhat later representative of the more highly specialized line which had taken to purely terrestrial habits.

These conclusions are in accord with the evidence to be derived from the relative age of the horizons in which these fossils are found. While there is little reliable stratigraphic data for comparison between the eastern and western Colorado localities, the evidence which has been adduced would indicate that *Brachiosaurus* comes from a horizon at least one hundred feet above the Cañon City quarry. However, various species of *Apatosaurus* and *Morosaurus* are found in the same horizons with both forms, so that the difference in time alone is not sufficient to account for the differences between these two related forms. We must, therefore, attribute these differences chiefly to digressive development.

PROBABLE HABITS.

The habits of the Opisthocœlia have been regarded as semiaquatic or at least marsh-dwelling. This conception was based largely upon the structure of the teeth, which are fitted for masticating soft, succulent vegetation, and upon the ponderous bulk of the animals which seemed best suited for aquatic locomotion. It is true that the massive structure of the vertebræ in such forms as *Apatosaurus ajax* bears some resemblances to the vertebræ in cetaceans. However, the writer has failed to discover in the skeletal structure of aquatic or semi-aquatic animals, either reptilian or mammalian, any of that fluting and hollowing of the vertebræ which have been interpreted as evidence of aquatic habits in the Opisthocœlia. This same effort at lightening the skeleton was regarded by an earlier English writer as evidence of aërial habits!

That which appears to the present writer to afford most reliable evidence as to habits is the structure of foot and limb. As pointed out by Hatcher, there is no evidence among opisthocœlians of that shortening or angulation of limb, or the broadening of foot, which is common to amphibious animals. Nor is there anything in the structure of the opisthocœlians which is not found in some terrestrial forms. The straight hind leg occurs in quadrupeds only among those forms which inhabit the uplands. Familiar instances of parallel development of this character are found in the proboscidea, dinocerata, etc. The short, stout metapodials and blunted phalanges characteristic of the Opisthocœlia would be as ill adapted for propulsion in water or upon marsh lands as are those of the elephant. The reduction in the number of claws offers further evidence along this line, and finds a parallel in the great ground sloths. In short, if the foot structure of these animals indicates anything, it indicates specialization for terrestrial locomotion.

In the genus *Brachiosaurus* there are very different proportions of fore and hind leg, of pelvis and thorax and tail, from those of the usual type of opisthocœlian dinosaurs. To harmonize with them we may expect that decided differences existed in the head and neck. The foot structure in *Apatosaurus* and *Diplodocus* may, as before stated, be regarded as highly specialized, but the length and slenderness of limb, the deep thorax, the broad sacrum, the expanded ilium, and the abbreviated tail of *Brachiosaurus* all point to a greater agility and a much better adaptation to terrestrial habits than is found in any other representative of the Opisthocœlia.

The varying structure of the dorsal vertebræ in the larger dinosaurs offers some interesting problems as to the habits of the animals. In some genera a relation between the length of the dorsal spines and the breadth of the zygapophyses is noticeable. We may well assume, with other writers, that the heavier forms, such as *Apatosaurus* and *Diplodocus*, which are provided with long spines in the sacral and posterior dorsal region, were adapted to rearing up on the hind legs as is represented in the conventional mounted skeleton of *Megatherium*. In these forms we find that the body is short and therefore well adapted to this habit. *Morasaurus* and *Camarasaurus* are less perfectly adapted to such a habit by reason of their shorter spines, but might well have been capable of assuming the upright position. The slender shaft of the ischium in the former genus could have hardly afforded sufficient support in the sitting posture. In all of these, however, it will be observed that the zygapophyses are strong and placed far apart, especially in the anterior dorsal region of *Apatosaurus*. Their separation is doubtless directly due to the bifurcate spines, but that arrangement was a concomitant of the development of a median set of dorsal muscles whose function it was to elevate the anterior portion of the body. The unusually strong zygapophyses served to support and control the ponderous shoulders and neck when the upright position was assumed. All of this bespeaks great mobility of the anterior portion of the body.

In *Haplocanthosaurus* we have noticed that the spines are short posteriorly, but reach their greatest length at the middle of the dorsal series. Together with this arrangement we find a more generalized structure of the zygapophyses and hyposphene, such as was noticed in *Morosaurus*. The former are moderately broad, but are nowhere placed far apart; the latter has a slightly greater development than in the above-mentioned genus. In *Brachiosaurus*, the zygapophyses reach the extreme reduction and the hyposphene-hypantrum articulation reaches the extreme development. The zygapophyses are crowded together near the median line in a way which would render impossible any considerable lateral movement of the body. The hyposphene articulation is well constructed to prevent lateral displacement. The strong thoracic ribs with widely divergent head and tubercle firmly anchored in the same horizontal plane doubtless added greatly to the strength of the vertebral column in this region. In this we recognize the rigid quadrupedal structure of the vertebral column.

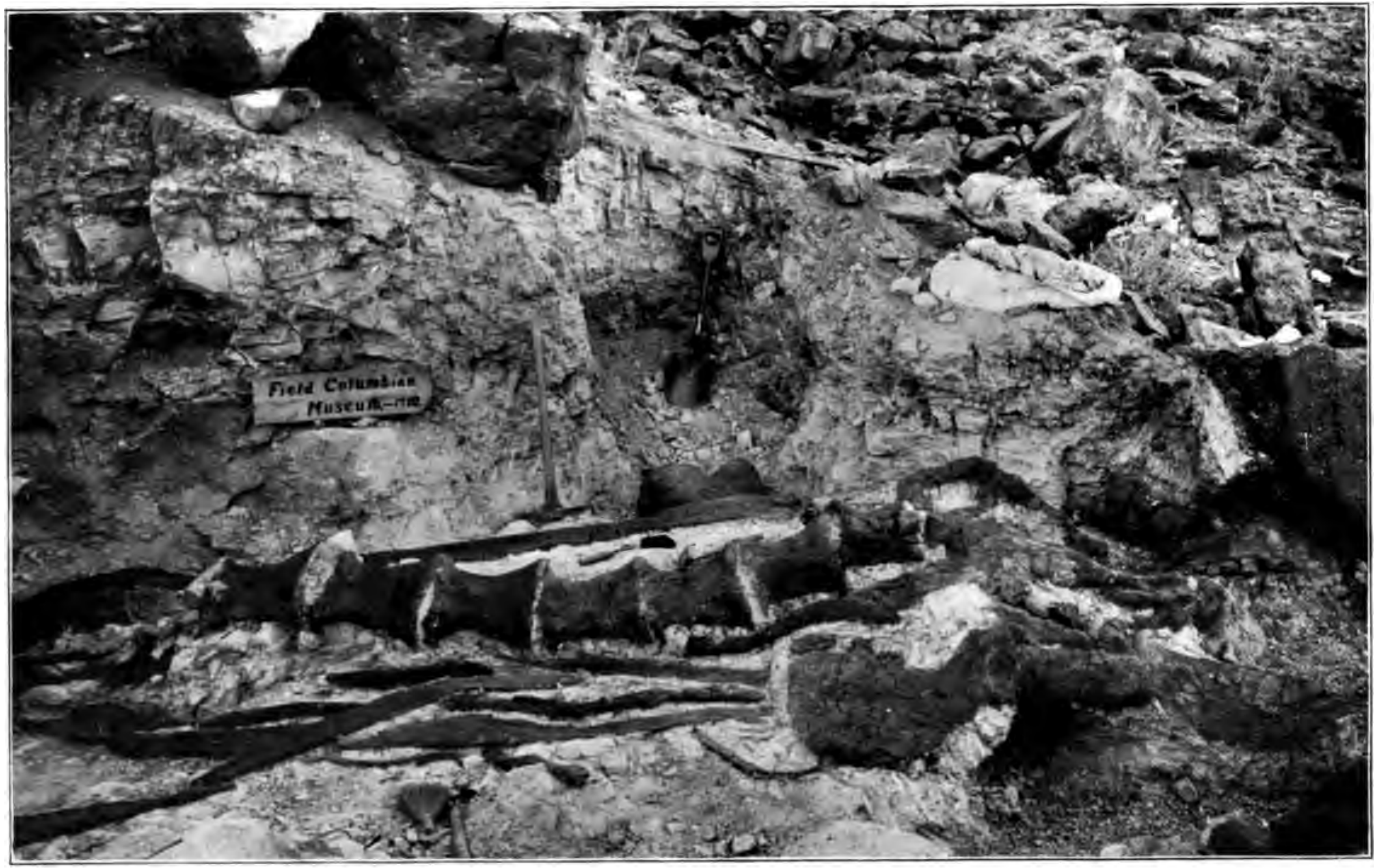
From the above considerations it will be seen that *Brachiosaurus* is the culminating type of a phylum, distinct from anything hitherto known in America. Its length of limb and bodily proportions show that it was fitted for purely quadrupedal movements. Though the structure of the feet and lower legs is unknown, there is every reason for believing that the animal was specialized in terrestrial habits. This fact would restrict its range to grounds where conditions were less favorable for its preservation and so account for its remaining so long unknown.

[illegible]

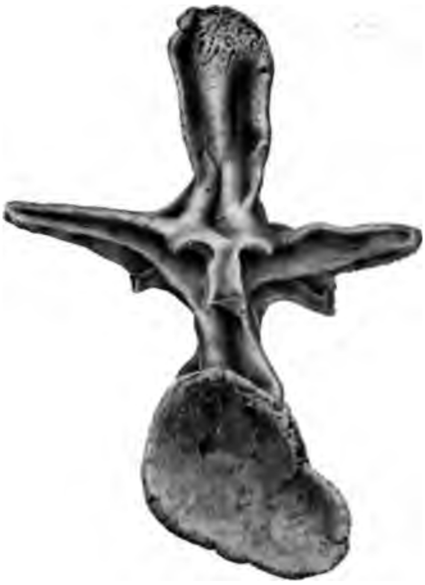
[illegible]

legs of *Brachiosaurus* indicate that its habits of locomotion were entirely quadrupedal.

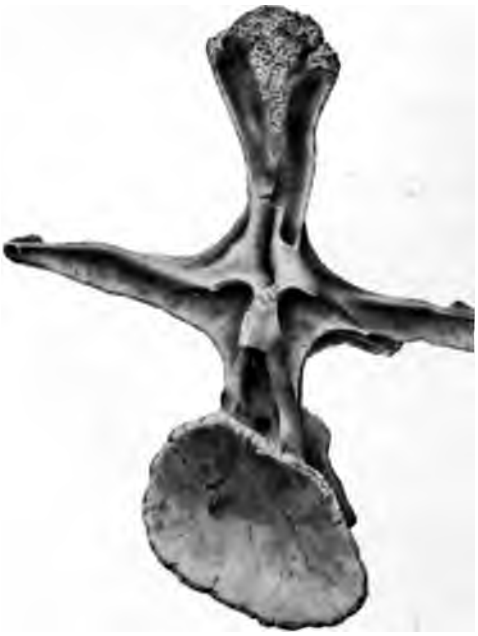
6. The foot structure in most opisthocœlians furnishes unmistakable evidence of terrestrial habits. The length of fore limb and bodily proportions of *Brachiosaurus* show that this form was more highly specialized for terrestrial habits than any other known member of this order.



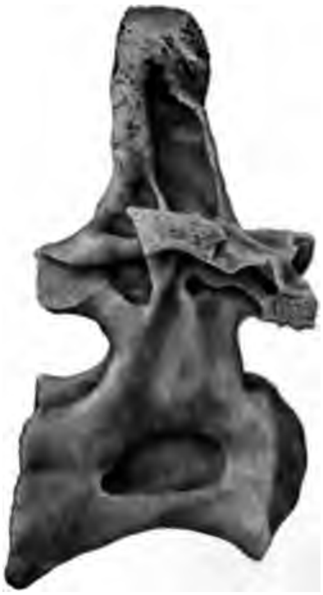
Dinosaur Quarry No. 13 near Grand Junction, Colorado. The dorsal vertebræ, sacrum, ilium, and ribs of the type specimen of *Brachiosaurus* are seen in position as found.



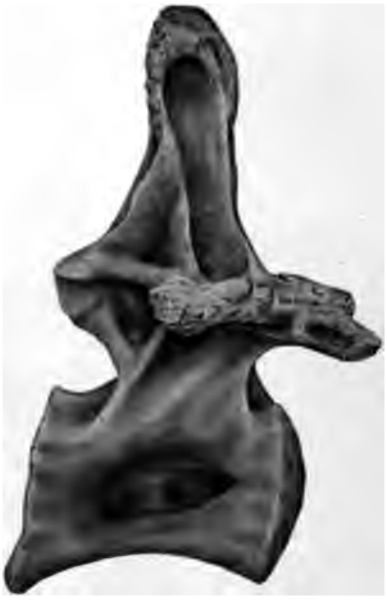
VI



VII



VI



VII

l 1/12 natural size.

PLATE LXXIII.

BRACHIOSAURUS ALTITHORAX.

FIG. 1. Lateral view of sacrum, 1/12 natural size. Anterior end at right.
FIG. 2. Inferior view of same, 1/12 natural size. Anterior end below.

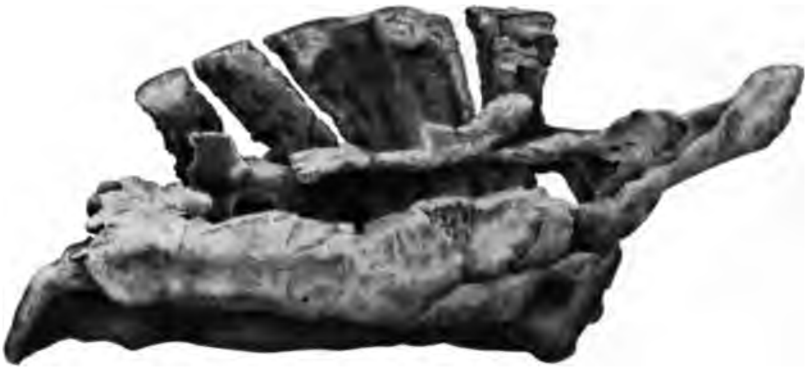


FIG. 1

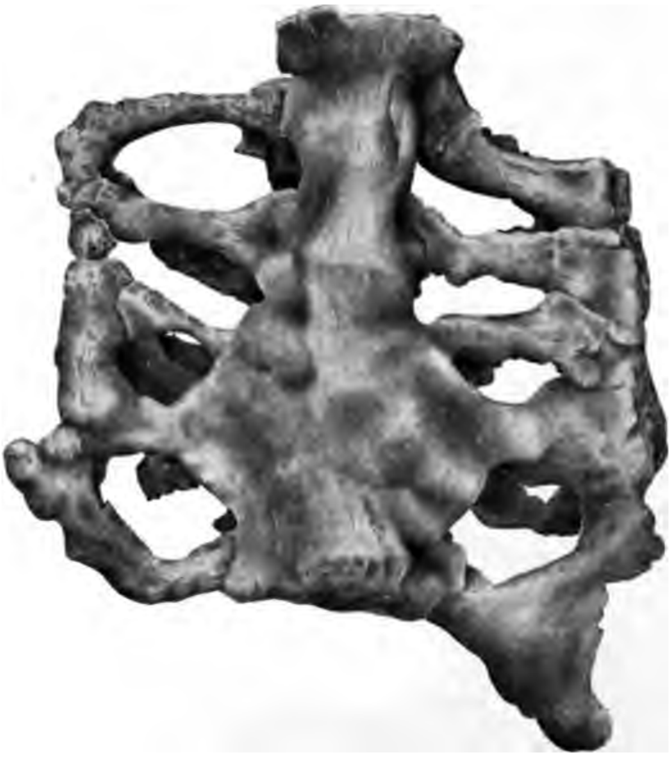


FIG. 2

PLATE LXXIV.

BRACHIOSAURUS ALTITHORAX.

FIG. 1. Head end view of right femur.
FIG. 2. Anterior view of same.
FIG. 3. Head end view of right humerus.
FIG. 4. Anterior view of same.
All $^1/_{14}$ natural size.

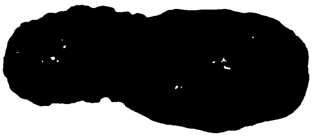


FIG. 1

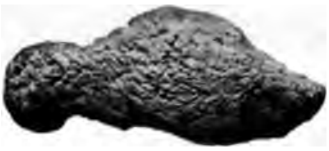


FIG. 3

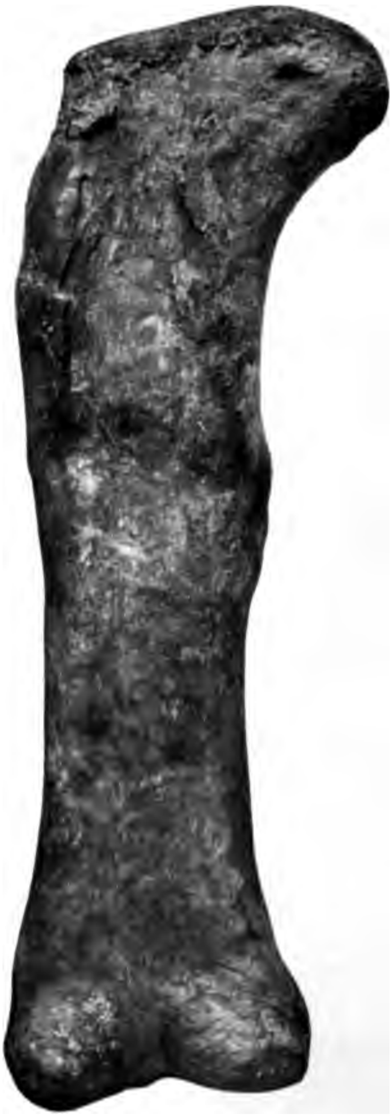


FIG. 2

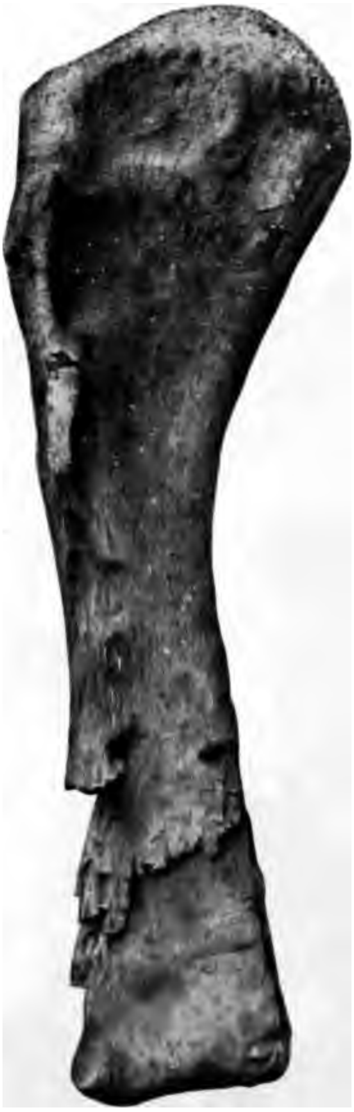


FIG. 4

PLATE LXXV.

BRACHIOSAURUS ALTITHORAX.

FIG. 1. Posterior view of second caudal vertebra.
FIG. 2. Lateral view of same.
FIG. 3. Lateral view of right ilium.
FIG. 4. Lateral view of left coracoid.
FIG. 5. Mesio-anterior view of the head of a thoracic rib.
All about 1/12 natural size.

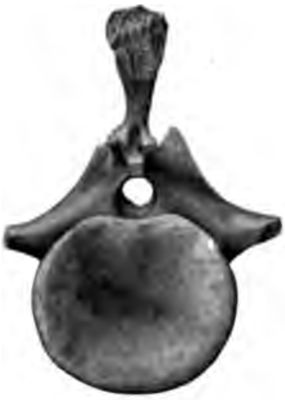


FIG. 1

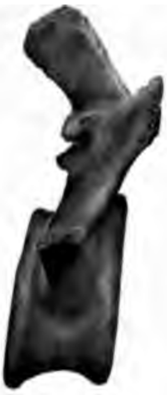


FIG. 2

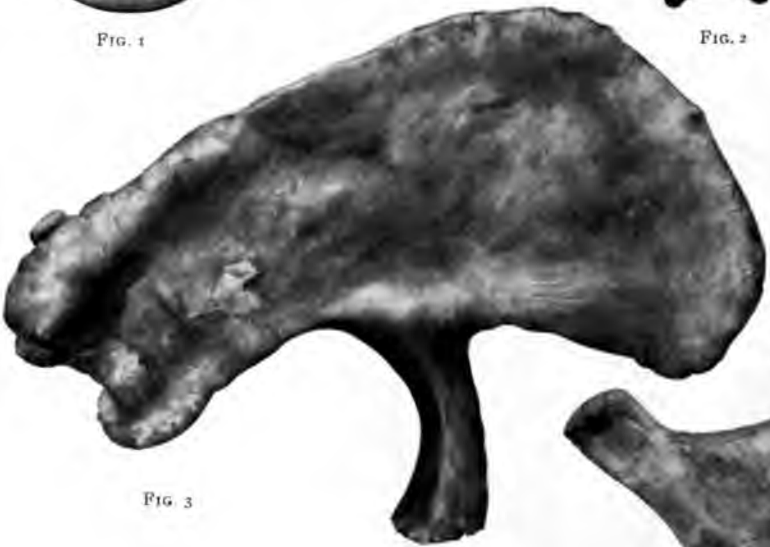


FIG. 3

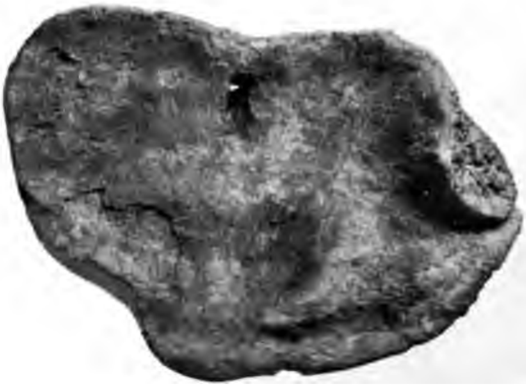


FIG. 4

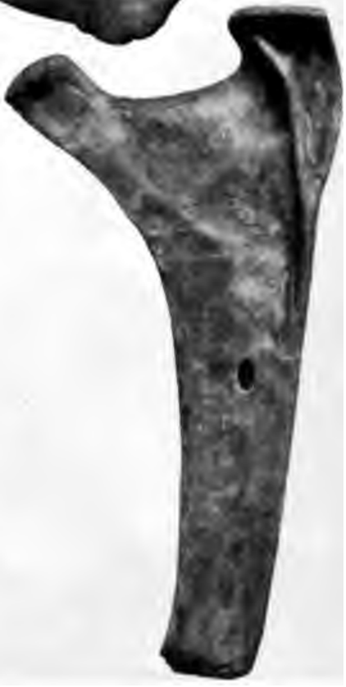


FIG. 5

FIELD COLUMBIAN MUSEUM.

PUBLICATION 110.

GEOLOGICAL SERIES. VOL. II, NO. 7.

THE CARAPACE AND PLASTRON OF BASILEMYS SINUOSUS, A NEW FOSSIL TORTOISE FROM THE LARAMIE BEDS OF MONTANA.

BY

ELMER S. RIGGS,

Assistant Curator, Division of Paleontology.

OLIVER CUMMINGS FARRINGTON, PH. D.

Curator of Geology.

CHICAGO, U. S. A.

February 1, 1906.

THE CARAPACE AND PLASTRON OF BASILEMYS SINUOSUS, A NEW FOSSIL TORTOISE FROM THE LARAMIE BEDS OF MONTANA.

BY E. S. RIGGS.

An unusually well-preserved shell of a tortoise (P. 12008) collected by the Museum Expedition of 1904 presents new and interesting characters. The specimen is evidently closely related to a form described* by Cope from the Judith River Beds of Montana as *Compsemys variolosus*. This, with a more complete specimen from the Belly River series of Alberta, was later referred† by Lambe to the genus *Adocus*, and finally by Hay to a proposed new genus, *Basilemys*‡ The size of the specimen under consideration is almost identical with that described by Lambe and the dermal markings are very similar, but it differs notably in the form of the anterior end of the plastron and the arrangement of gular shields. The median sulcus of the plastron is remarkably sinuous, crossing and recrossing the median line and often deviating widely from it. On account of this character the specific name *sinuosus* is proposed for it. It is provisionally referred to *Basilemys* pending the definition of that genus.

The specific characters are as follows: Anterior end of plastron produced into a thick rounded knob; gular shields long and narrow and meet at the median line; median sulcus unusually sinuous.

The specimen as a whole is in a fine state of preservation. It was found in a bed of hard but uncemented sand containing bones of *Triceratops*, *Trachodon*, and other characteristic Laramie fossils. The shell was lying on the plastron in its normal position. It has been somewhat flattened by compressure in the vertical direction. The carapace is complete with the exception of a few fragments missing from the vertebral region and a section from the right side; including the posterior half of the second and the anterior half of the third pleural plates, together with the greater part of the fifth and the anterior part of the sixth peripheral plates. Much of the contact between the carapace and plastron is also lost. The remainder of the plastron is preserved entire. However, the inferior surface is modified by compressure so as to be deeply concave.

---

*Pro. Acad. Nat. Sci. Phila. 1876, p. 257.

†The Ottawa Naturalist, Vol. XVI. p. 63.

‡Nomen Nudem, Bull. U. S. Geol. Surv. Nov. 179, p. 445.

The shell is in general structure broad and low, flat and emarginate at the interior end, but steep posteriorly. The carapace and plastron are firmly united by a wide bridge which extends more than half the entire length of the shell. The whole of the free surface is marked by pittings which vary in depth, structure, and arrangement in different parts of the shell. The horny shields are outlined by narrow sulci which are plainly marked in the vertebro-costal region, and in the plastron, though less conspicuous between the marginals. The sutures joining the bony plates are everywhere closed, so that in some places they cannot be traced by the aid of a lens. The centra of the dorsal vertebræ have been detached and lost from the specimen entirely. The neural plates bear on their inferior surfaces an interrupted median ridge indicating the attachment of the neural spines. The proximal ends of the pleural plates bear stout tubercular processes for vertebral attachment. Plate LXXVII.

The *carapace* is relatively thin throughout. The anterior end is unusually flat, a character which has evidently been accentuated by compressure in fossilization. The nuchal border is rounded and indented by a wide concavity. Elsewhere the free margin is drawn to a sharp angle. The posterior end is markedly convex in the pygal region. The margin is slightly recurved over the femora, but uniformly convex and overhanging at the median line. Plate LXXVII.

The *neural plates* are irregularly hexagonal, but vary in size and in outline. A certain amount of asymmetry is also noticeable in them. The first is broadly coffin-shaped, with the large end directed backward. It articulates laterally with the first pair of pleurals, postero-laterally with the second pair, and posteriorly by a concave line with the second pleural. The second is sub-ovate in outline and notably smaller than the first. Its pleural articulation is confined to the second pair. The third neural is a trifle smaller than the first and has an outline similar but reversed in position. Thus it articulates antero-laterally with the second pair of pleurals and laterally with the third pair. The entire fourth and part of the fifth are missing from this specimen. They were evidently narrower than the third but similar in form. The sixth is notably asymmetrical. The anterior end and right side have the usual form, but the left side is elongate so as to articulate with the whole mesial end of pleural VI and postero-laterally by a short line with pleural VII. The seventh neural is thus excluded from its normal articulation on the left with pleural VII, and is correspondingly asymmetrical. It is also much smaller. The eighth neural is much shortened antero-posteriorly and lies opposite the suture between pleurals VII and VIII. A ninth irregularly rounded plate intercolated between the last pair of costals may be regarded as a post-neural.

The *pleural plates* extend only about two-thirds of the distance from the neural suture to the margin of the carapace. Their articulation with the neurals has been described in the preceding paragraph. Distally they articulate with the marginals, breaking joints in a mosaic pattern. Pleurals I to III inclusive are directed obliquely forward. Pleural IV stands at a right angle to the median line. From this point the remainder of the series becomes more and more directed obliquely backward until the last pair conforms to the wide A-shape of the first pygal. Pleural I is much the broadest of the series, articulating anteriorly with the nuchal and peripherals one and two. Distally it abuts the whole mesial border of peripheral three and a small anterior portion of four. Pleural II is long and narrow, meeting only two-thirds of peripheral four. Pleural III is widest at the distal end, articulating antero-laterally with the fourth and laterally with the fifth peripheral. Pleural IV is uniform in width, and has a distal articulation similar to the perceding. Pleural V is slightly expanded toward the extremity and presents an almost equal surface to marginals six and seven. The suture between Pleurals V and VI is unusually sinuous. The latter element is noticeably narrower and has its distal articulation similar to the preceding. Pleural VII is shorter, and much narrower at the mesial end. It articulates distally with peripheral eight by a short suture, but chiefly with nine. Pleural VIII is shortest and smallest of the series. It arises from the eighth and ninth neurals, and is more uniform in width than the preceding. It meets peripheral nine in a short antero-lateral suture as well as half the mesial surface of peripheral ten.

The first *pygal plate* has the form of a wide A. Its lateral wings are co-extensive with the last pair of pleurals, with which they articulate anteriorly. Laterally they abut a third of the mesial surface of peripheral ten. The posterior surface is concave to receive the rounded surface of the succeeding element. The second pygal is a wide irregular figure, convex on the anterior surface and bounded by three concave facets posteriorly. These facets articulate with the eleventh pair of peripherals and the third pygal. Laterally this bone also presents a small pair of surfaces to the postero-lateral faces of the tenth pair of peripherals. The third pygal is not more than half as large as the second and is sub-hexagonal in outline.

The *peripherals* are eleven in number exclusive of the nuchals and last pygal. The series as a whole is unusually deep, especially in the lateral region where the plates above the angle of the carapace are more than half the length of the adjacent pleurals. Only the last pair is covered entirely by the marginal shields. The nuchal differs from the common hexagonal type in that the anterior border forms a reëntrant angle at the median line. The peripheral bones gradually increase in depth from first to fourth. The fourth, fifth, and sixth are similar in size and are largest of the series. With the seventh there is a decided reduction in antero-posterior diameter. The ninth and tenth diminish rapidly in length, the eleventh is much the smallest of the series. The tenth presents an equal surface to articulate with the eighth pleural and the first two pygals. Peripherals three to seven inclusive form the bridge.

The *vertebral shields* are notably variable in outline. The first has the form of an irregular truncated pyramid with its base at the anterior marginal suture. In this specimen it is quite asymmetrical. The second, third and fourth are much longer than wide. The second and third are sub-rectangular in outline and nearly equal in size. The fourth is somewhat smaller, narrower at the posterior end and more irregular in outline. The fifth is the largest of the series. It has the form of a wide triangle whose base is at the posterior marginal suture.

The *costal shields* are four in number. The first has the form of a quadrant of a circle whose center is at the mid-lateral border of vertebral II. It overlies the greater part of the first and half of the second pleural, as well as parts of the first four peripheral bones. The second and third costals are rectangular in outline. The second is somewhat broadest in its antero-posterior diameter and extends over the posterior half of the second, all of the third and the anterior half of the fourth pleural plates, as well as parts of the fourth, fifth and sixth peripherals. The third costal shield bears a similar relation to the fourth, fifth and sixth pleurals, and the sixth, seventh and eighth peripherals. The fourth costal shield is an irregular quadrilateral and is the smallest of the series. Its relation to the neural and peripheral plates is similar to that of the second and third. The intercostal sulci have the usual position opposite the middle of the vertebral shields.

The *marginal shields* are twenty-five in all. The sulcus separating them from the vertebrals and costals falls far without the pleuro-peripheral suture and is little more plainly marked than those in the vertebral region. The nuchal shield is very small. It is narrow in its superior aspect but rapidly widens as it rounds the anterior margin. The first pair of marginals are long and narrow; the second and third increase regularly in breadth. The fourth to seventh, inclusive, overlie the bridge. Their distal articulation will be described with the plastron. The eighth, ninth and tenth diminish slightly in depth in the order named. The eleventh increases rapidly in depth toward the mesial border. The pygal is deepest of the series and is paired.

The *plastron* is suggestive of great rigidity and strength as indicated by the wide bridges with thickened buttresses and firmly interlocking sutures, the massive anterior process formed by the epiplastra, and the thickened and rugose borders. The pittings are more deeply marked than on the carapace, and the arrangement of shields is unusually complicated. In its entire length the median sulcus crosses the median suture fourteen times. At no point does it coincide with the median suture. Compared with the plastron of *B. variolosus* as figured by Lambe* there is a great similarity. However, the epiplastrals in this form are more produced, the entoplastron noticeably larger, the gular shields meet at the median line, and the median sulcus is much more sinuous. Plate LXXVIII.

The *epiplastra* unite at the median suture to form a thick and rounded knob, which may be termed the gular eminence. The distal ends appear on the inferior surface as a pair of wing-like processes which are directed postero-laterally. The entoplastron is subhexagonal in outline and one-third broader than long. Its anterior margin joins the epiplastra in two approximately straight lines which meet in an angle of sixty degrees. The lateral borders are short, the posterior angle very obtuse. The hypoplastra are somewhat larger than the hyoplastra. In this specimen there is a break in their connecting suture at the median line. The former articulate laterally with peripherals three, four and five, and postero-laterally they present a short articulating surface to peripherals six. The hyoplastra articulate laterally with peripherals six and seven. The xiphiplastra extend forward almost to the femoral notches. On the superior surface the gular eminence terminates in a single short median ridge, and is flanked by a pair of marginal ridges which extend half way to the humeral notches. The entoplastron bears on a pair of low converging ridges the facets for articulation with the precoracoids. The xiphiplastra bear a similar but larger pair of facets for ligamentary union with the pubic process. From the femoral notch to the median line the margin is elevated to form a sharp ridge, deeply pitted on the free surface.

---

*Geol. Surv., Canada. Vol. III. part II, page 39.

The *dermal shields* of the plastron are very complex in arrangement. The intergulars are similar on the inferior surface to those of *B. variolosus*, but superiorly they are extended to cover the protruding gular process. Between them the median sulcus twice crosses the median suture. The gulars are long and narrow, and meet at the median line. The humerals are relatively smaller than in *B. variolosus.* They present for union at the median line a surface barely a half-inch in length. The pectoral shields as a pair are similar in outline to those of the species cited, though they extend somewhat farther backward mesially. Between them the median sulcus departs from the median line in a series of meanderings in which it crosses the median suture five times. In the abdominals it follows almost parallel with the suture making a single digression near the posterior border. The abdominals send backward a pair of peculiar narrow processes between the inguinals and femorals to the border of the femoral notch. The femorals are sub-quadrangular in outline, extending laterally to the border of the femoral notch. In the anals the median sulcus presents the most fantastic tracery, crossing the median suture in a series of wide loops, departing from it, in one instance, nearly two inches and finally returning to it at the posterior margin. On account of portions missing at the lateral angle of the carapace it cannot positively be determined whether the marginals are divided into an inframarginal series. From the fact that no evidence of a dividing sulcus can be made out on either side, as well as the opposite position of the vertical sulci on each side of the gap, it is assumed that the series is not divided into marginals and inframarginals, respectively.

From the narrow lateral extremities of the pectorals radiate three wedge-shaped shields. The anterior and smallest is the axillary shield which overlies the axial buttress and extends upward along the free margin of the carapace to join the second nuchal. The other shields radiating from this point are the fourth and fifth marginals. The sixth marginal is very broad at its ventral border, joining nearly the whole lateral surface of the abdominal shield. Two pairs of shields converge at the postero-lateral angle of the abdominals. The most anterior is the seventh marginal, which narrows mesially almost to a point. Back of this lies the inguinal shield which overlies the posterior or inguinal buttress.

---

*Proc. Acad. Nat. Sci. Phila. 1876, p. 257.

The sculpturing of the shell in members of this genus has been variously described. In his original description* of the type species *B. variolosus* Cope described the dermal markings as follows: "The sculpture consists of round fossae, which are deeply impressed, and are arranged quincuncially, so that their borders never form straight lines. The latter are also more or less angulate on the edges, so that the surface has a more than usually rugose character." Of the species *B.* (*Compsemys*) *imbricarius* he writes as follows:* "The character of this sculpture distinguishes the species and, in the present instance, in a special manner. It consists in the *C. imbricarius* of excavations bounded on the sides by a short ridge each, which alternate with each other. Thus each bounding ridge terminates abruptly at the fundus of one of the fossae, while the other end of the fossa rises and contracts to another ridge." In the more complete specimen described by Lambe as belonging to *Adocus variolosus* the markings are described as follows:† "The sculpture consists, when most rugose, of well-excavated pits of rounded hexagonal outline arranged quincuncially; the dividing ridges are angular and narrower than the pits are wide, their angularity and height being more pronounced at the junction of every three pits with each other."

It will be noted that the quotations from Cope's description of *B. imbricarius* and Lambe's characterization of the sculpture in *B. variolosus* describe very similar markings. Moreover, the various types of markings indicated by these three descriptions are all to be found in various parts of the specimen under consideration. In fact, the sculpture in various regions of carapace and plastron varies so widely that no area could be taken as typical with the assurance that fragments from other parts of the shell could be recognized from it.

The pittings are most conspicuous and most regular on the plastron and about the margin of the carapace. In the vertebral region they are least conspicuous and without any regular arrangement. On the superior surface of the gular process and the anterior half of the femoral shields there is to be found the type of sculpture described in *B. imbricarius* in which a sharp ridge terminates abruptly at the fundus of the succeeding pit. It is noticeable, however, that in those portions of the femoral shields which overlie the xiphiplastra the arrangement suddenly changes to a series of irregular diagonal rows.

---

*Ibid.

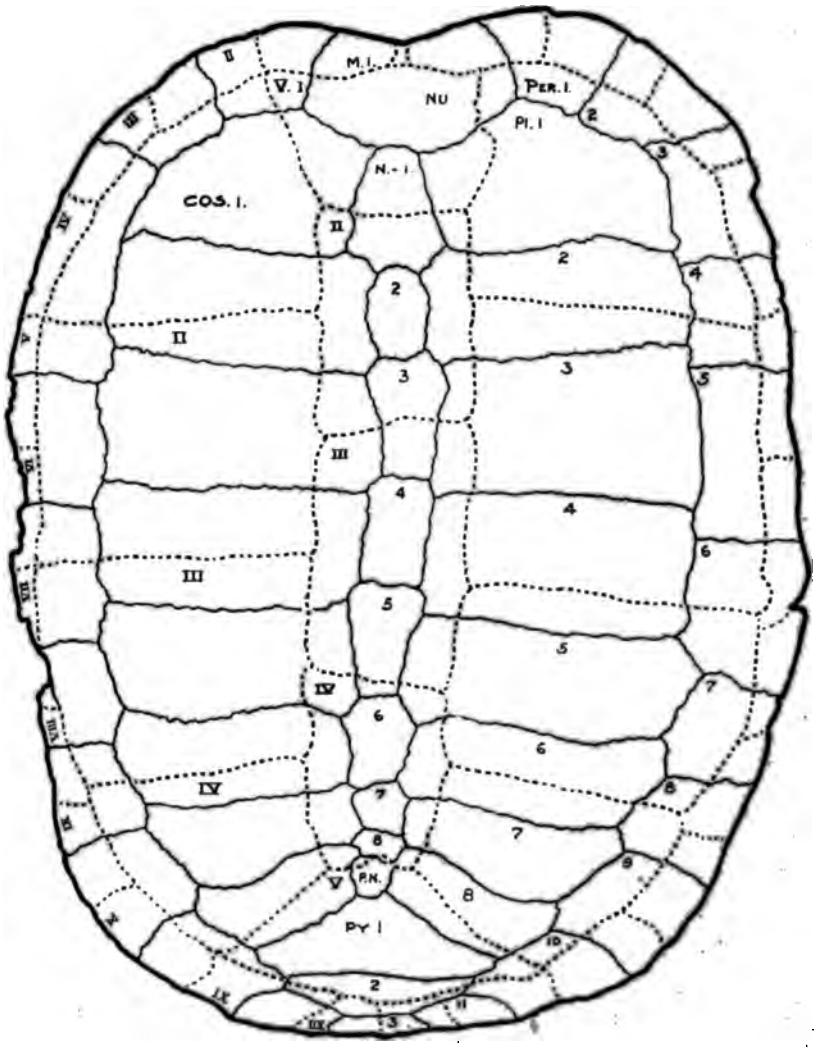
†Geol. Surv. Canada. Vol. III, part p. 40.

Similarly on the lateral surface of the gular process the markings fall into straight rows in which the pits of adjacent rows alternate so as to form diagonal lines. Thus the pits are in regular rosettes — patterns of six around one. In other parts of the plastron may be occasionally recognized groups of fives, of fours and of threes, but for the most part no regular arrangement is to be recognized.

It is, therefore, probable that if the whole carapace and plastron of *B. variolosus* and *B. imbricatus* were known the same regional variation would be found to obtain. At all events, little reliance can be placed upon the depth or arrangement of pittings as bases for specific determination in this genus.

MEASUREMENTS.

	M
Length of carapace at median line	.705
Breadth of carapace	.565
Length of plastron	.650
Breadth of hypoplastra	.480
Length of bridge	.360
Greatest breadth of nuchal plate	.145
Least breadth of nuchal shield	.007
Greatest breadth of first pleural plate	.112
Greatest length of third pleural plate	.205
Greatest breadth of anterior pygal	.170
Breadth of entoplastron	.148
Thickness of epiplastra at gular eminence	.060



BASILEMYS SINUOSUS, × 2/11.

Nu., nuchal plate.
N. 1 to 8, neural plates.
P. N., post-neural plate.
Per. 1 to 11, peripheral plates.

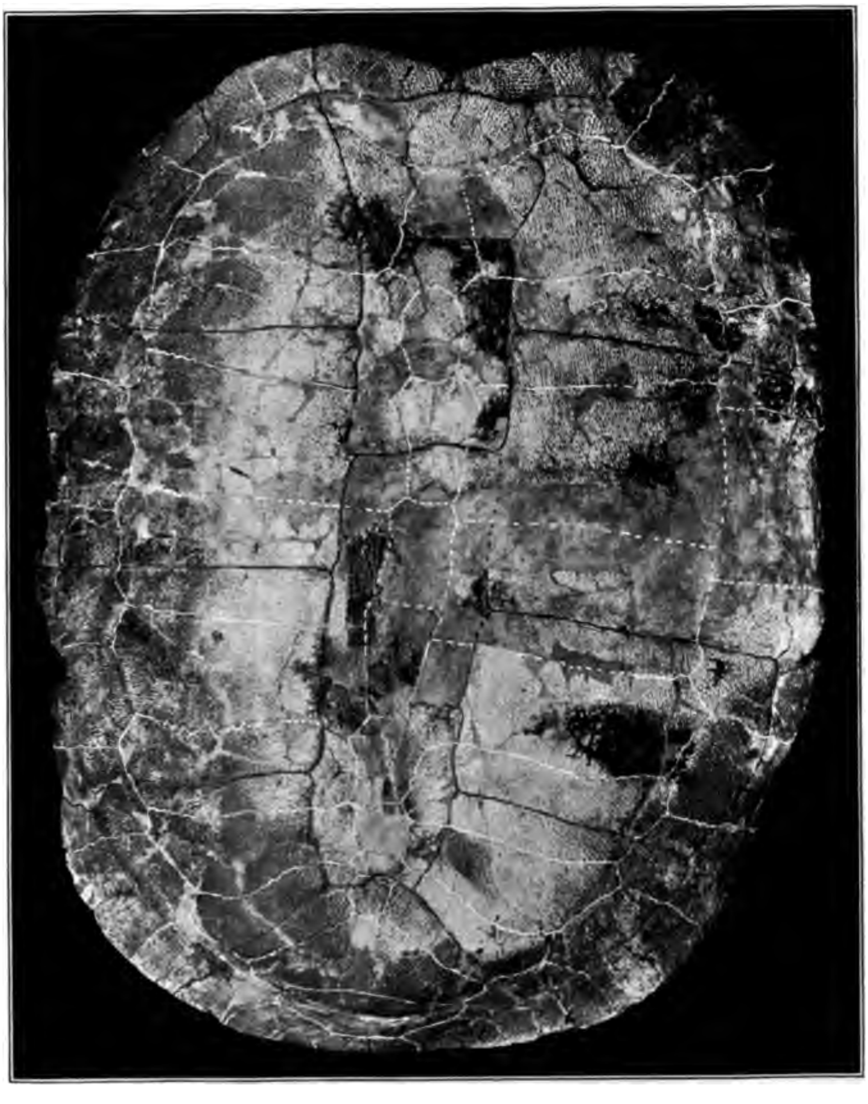
Py. 1 to 3, pygal plates.
V. I to V, vertebral shields.
Cos. I to IV, costal shields.
M. I to XII, marginal shields.

Similarly on the lateral surface of the gular process the markings fall into straight rows in which the pits of adjacent rows alternate so as to form diagonal lines. Thus the pits are in regular rosettes—patterns of six around one. In other parts of the plastron may be occasionally recognised groups of fives, of fours and of threes, but for the most part no regular arrangement is to be recognised.

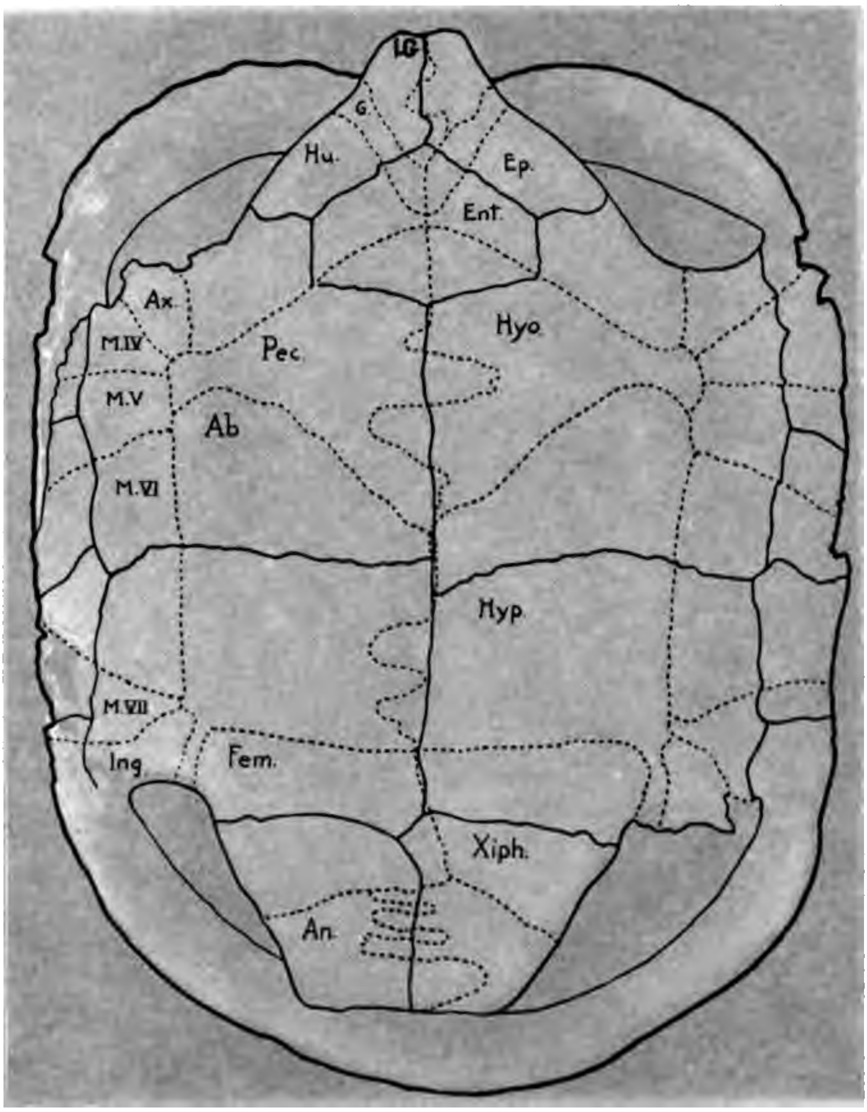
It is, therefore, probable that if the whole carapace and plastron of *B. variolosus* and *B. [illegible]* were known the same regional variation would be found to obtain. At all events little reliance can be placed upon the depth or arrangement of pittings as taken for specific determination in this genus.

MEASUREMENTS.

	M.
Length of carapace at median line	.292
Breadth of carapace	.272
Length of plastron	.270
Breadth of hypoplastra	.189
Length of bridge	[illegible]
Greatest breadth of nuchal plate	.048
Least breadth of nuchal shield	.007
Greatest breadth at first neural plate	.032
[illegible]	.005
[illegible]	.170
[illegible]	.158
[illegible]	.060



Carapace of *Basilemys sinuosus*, dorsal view, × 2/11.

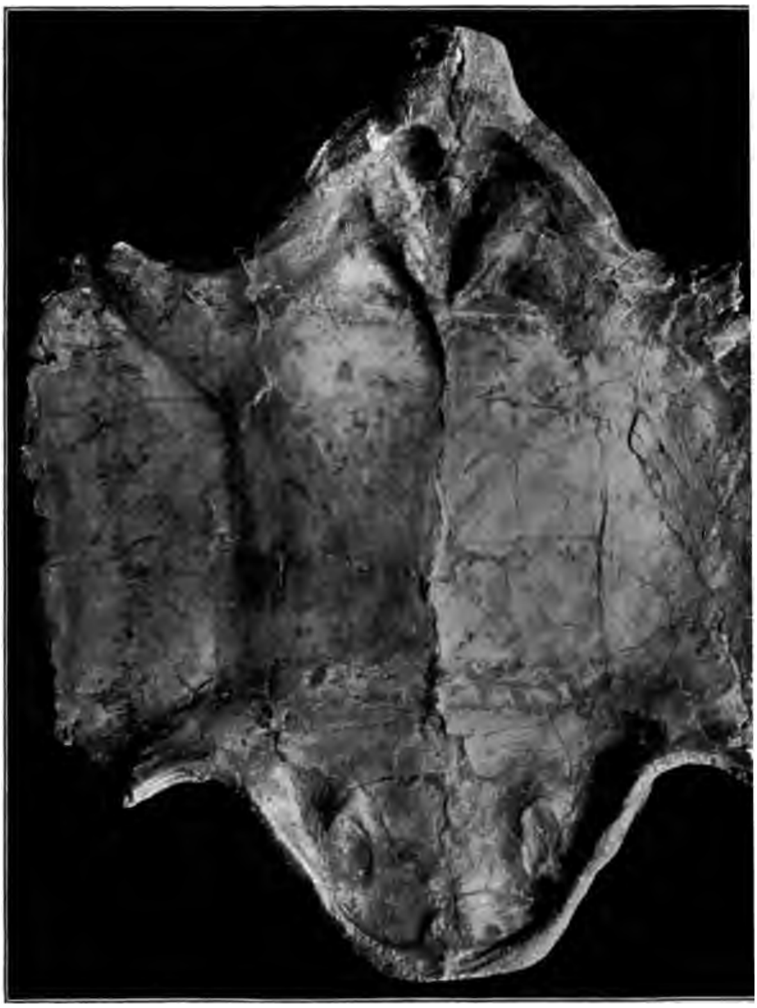


BASILEMYS SINUOSUS, × 2/11.

Ep., epiplastron.
Ent., entoplastron.
Hyo., Hyoplastron.
Hyp., Hypoplastron.
Xiph., xiphoplastron.
I. G., intergular shield.
G., gular shield.

H., humeral shield.
Pec., pectoral shield.
Ab., abdominal shield.
Fem., femoral shield.
An., anal shield.
Ax., axial shield.
M. IV to VII, marginal shield.

Ing., inguinal shield.



Plastron of *Basilemys sinuosus*. visceral surface, × 2/11.

FIELD COLUMBIAN MUSEUM.
PUBLICATION NO. 113.
GEOLOGICAL SERIES. VOL. II, NO. 8.

A LIST OF DEVONIAN FOSSILS COLLECTED IN WESTERN NEW YORK, WITH NOTES ON THEIR STRATIGRAPHIC DISTRIBUTION.

BY
ARTHUR WARE SLOCOM,
Assistant in Paleontology.

OLIVER CUMMINGS FARRINGTON, PH. D.
Curator, Department of Geology.

CHICAGO, U. S. A.
June 1, 1906.

A LIST OF DEVONIAN FOSSILS COLLECTED IN WESTERN NEW YORK, WITH NOTES ON THEIR STRATIGRAPHIC DISTRIBUTION.

BY ARTHUR W. SLOCOM.

The material upon which this paper is based, was collected during the month of September, 1904, and is now a part of the Paleontological collections of this Museum. Especial effort was made while collecting, not only to obtain as complete a fauna as possible at each locality visited, but to have the number of specimens collected of the various species represent, as nearly as might be, their relative abundance at the different localities.

In the Hamilton or Middle Devonian rocks of Western New York and Canada there are three well-defined beds of varying thickness but of constant lithological characters. The upper of these beds is a shale called the Moscow shale; the middle bed is a crystalline limestone varying in thickness from 1½ to 3 feet, called the Encrinal limestone; and the lowest bed is the Hamilton shale. The Encrinal limestone is present at so many of the outcrops, and is so easily recognized that it serves as a datum line for correlating the shales either above or below it. At none of the localities visited by the writer was there enough of the beds exposed to give any idea of the thickness of the series, but measurements made at other places by other authors show that in a general way the beds may be said to gradually thin out towards the West. Thus at *Utica, New York, where the measure was obtained from a well, Prosser found a thickness of 1,142 feet.

At the †Livonia salt shaft in Livingston county, about 124 miles west of Utica, Luther reports the thickness of the beds as 517 feet, and at the †Crystal salt well near Wyoming, about 23 miles farther west, a thickness of 407 feet. At ‡Eighteen Mile Creek near Buffalo, about 45 miles west of Wyoming, Shimer and Grabau report that the beds measure only 76 feet. At ‡Thedford, Ontario, about 130 miles still farther west, a thickness of 81 feet is reported by the same

---

*Am. Geologist, Vol. VI, p 202.

† 47th N. Y. State Museum Report, p. 258.

‡ Bull. Geol Soc. of Am., Vol. 13, p. 162.

authors. Thus it appears that, in passing from Utica to Eighteen Mile Creek, a distance of a little less than 200 miles, the beds thin from 1,142 to 76 feet. In the next 130 miles, however, there is comparatively little change in thickness.

The Moscow and Bethany localities have been well known collecting grounds for many years. H. A. Green* called attention to them as far back as 1866, and still the supply of well preserved fossils is apparently as good as ever.

Moscow: The outcrop at Moscow, from which the Moscow shale received its name, afforded to the writer its characteristic fauna. Fossils were most abundant at the exposures along the creek on the farm of Mr. W. H. DeForrest (Plate LXXIX) about a mile northeast of town. Another exposure was found about a quarter of a mile north of the station where a creek passes under the railway track, and by following the creek up stream, some brachiopods were obtained.

Near East Bethany, six exposures were visited. These are indicated on the map (Plate LXXX) by the field numbers, B4 to B9 inclusive.

B4 is situated about a mile and a half west of the station at the point where the railroad cuts through the top of the divide between the valley of the Genesee River, which empties into Lake Ontario, and that of Tonawanda Creek, which empties into the Niagara River only a short way from Lake Erie. This exposure is about three quarters of a mile in length and has a depth of perhaps 15 feet where the road crosses it. From this point it tapers down to nothing at each end. This ridge is the highest elevation of land in this locality. Fossil corals and brachiopods are especially abundant here, but many of the other classes of invertebrates are also found. *Hypocrinus fieldi*, described by Frank Springer and the author, came from this locality. The Encrinal limestone appears at the top of the exposure so that the shale from which the fossils were obtained is the upper part of the Hamilton shale.

B5 is situated about a mile southeast from the station at the Peck & Wood tile factory. Here the shale is weathered so that it can be plowed. A layer about a foot thick at the top is very rich in brachiopods. [illegible] and [illegible] the hair-like spines preserved. [illegible] abundant and attains [illegible] a much larger size than at Moscow, or at any of the other outcrops at Bethany, with the possible exception of B9. Many of the shells of this species have parasites attached to them. Among these parasites occur three species of bryozoans, worm tubes, and an inarticulate brachiopod. Below this layer rich in brachiopods, the shale is comparatively free from fossils. A few specimens of *Pleurodictyum stylopora* were the only fossils obtained here by the writer.

---

* [illegible]

[illegible]

B6 is situated on the roadside between the tile factory and the station. It is an outcrop of a hard, black shale, lying quite a little higher than either B5, B7, or B9, but whether it is above the Encrinal limestone, the writer was unable to determine. This outcrop was quite small and comparatively unimportant.

B7 marks a number of exposures along the banks of White Creek, a short distance southeast of East Bethany. This locality afforded corals, brachiopods, etc. Monroe* reports finding *Goniatites* in pyrite nodules at this place, but none was secured by the writer.

B8 is located a mile and a half west of B4, at the point where a small tributary of Tonawanda Creek runs near the track. Along the banks of the tributary are piles of weathered shale in which quantities of bryozoans, corals, and gastropods were found. Just west of here where the road crosses the track, a cut affords a good exposure of a black laminated shale similar to certain upper layers at Moscow, which is practically barren of fossils, but on top of this, is a thin layer in which some large brachiopods were found. The shale near the brook does not appear to be *in situ*, and probably was brought there at the time the railroad was built, from a small cut just east of its present position, where a similar shale is found. The Encrinal limestone is exposed in the bed of this brook, with a moderate dip towards the west. This would determine both the black and the fossiliferous shales to belong to the upper group, or Moscow shale. While these beds are much lower topographically than those at B4, they are undoubtedly higher geologically.

B9 is found by following White Creek up stream from near the tile factory, to several exposures where brachiopods abound. As might be expected from the proximity of their location, the fossils found at these outcrops are similar to those of B5. These outcrops appear to be the upper portions of the beds whose base is exposed in the clay pit at B5.

WINDOM is situated about 8 miles southeast of the business center of Buffalo. Near the railway bridge the Encrinal limestone is exposed with both the Moscow and Hamilton shales. All may also be seen along the banks of the South Branch of Smokes Creek. Between the railroad and the creek, large piles of weathered shale and blocks of limestone are to be found in which fossils are abundant. Brachiopods and corals are the predominating fossils, and a fine series of well preserved specimens was collected, but as most of them came from the dump piles or talus, they are of little value in determining the distribution of the species in the three horizons.

---

* Bull. Wis. Nat. Hist. Soc., Vol. 2, p. 57.

After the identification of this material, the various species were tabulated to see if the geological position of B5, B6, B7, and B9 in relation to the Encrinal limestone could be determined. Upon comparison of these faunas with those of Moscow, B4, and B8, it was not only found impossible to determine the position of the unknown faunas, but also it was found that the Moscow fauna did not bear the relation to those of B4 and B8, that might be expected. In order to make the range of localities and faunas studied as complete as possible, published lists of Hamilton fossils by various authors from other localities were referred to and mention of any of the species collected by the present writer noted. It was then found by a study of the table, that while at different localities, the faunas could readily be separated into "upper" and "lower," on correlating the localities, these distinctions could not be maintained. Thus *Aulopora serpens* occurs at Bethany in both the Moscow and Hamilton beds, while at Thedford it is only reported from the Moscow, at Eighteen Mile Creek only from the Hamilton, and at Cayuga Lake, from both. The two species of *Craspedophyllum* are not reported below the Encrinal limestone at either of the other localities, but at Bethany *C. archiaci* is very abundant all through the series, and *C. subcæspitosum* is found only in the Hamilton. *Favosites argus* is reported only from the Moscow at Cayuga Lake, and only from the Hamilton at Eighteen Mile Creek, but at Bethany it is found in both layers. *Streptelasma rectum* is reported as extending through the series, and is so found at Bethany, but the allied species *S. ungula* has been reported only from the Moscow. At Bethany, however, it is found in both the Moscow and Hamilton. The same may be said of *Rhipidomella vanuxemi* and *R. penelope*. They are both found through the series at Bethany, but while the former is so reported, the latter is reported only from the Moscow. *Stropheodonta concava* is reported only from above the Encrinal limestone at Thedford and Cayuga Lake, and only in and below the Encrinal limestone at Eighteen Mile Creek, but at Bethany it occurs both above and below. *Stropheodonta demissa* is found throughout the series at Bethany, and also at Thedford, but at Eighteen Mile Creek it is reported in the Encrinal bed and below, and at Cayuga Lake only in the Hamilton. *Tropidoleptus carinatus* is found through the series at both Bethany and Cayuga Lake, but at Eighteen Mile Creek in the Encrinal limestone and below, and at Thedford only in the Hamilton.

It is of interest to note that in the Bethany fauna the range of some species, e. g. *Aulopora serpens* and *Tropidoleptus carinatus* corresponds to the Cayuga Lake fauna; that of others, e. g. *Strophcodonta demissa*, corresponds to the Thedford fauna, and *Stropheodonta concava* and *Favosites argus* have as great a range at Bethany as at all the other localities combined. Hence it is not safe to determine the position of isolated beds, in regard to the Encrinal limestone, by the composition of the fauna. A similar conclusion was reached by Cleland* in his study of the Hamilton beds at Cayuga Lake.

The following table represents the amount of material collected by the writer, with the exception of the bryozoans from "B8." Of these a large series, both of species and specimens, was secured, but as they have not yet been identified, they are not included. The figures against each species in the table indicate the number of specimens collected by the writer. The letters indicate that the same species have been reported by other authors from Thedford, Eighteen Mile Creek, or Cayuga Lake, and the particular letter indicates the bed in which they were found. Thus M, indicates Moscow shale; E, Encrinal limestone, and H, Hamilton shale. The papers consulted for mention of these species are the following: Hamilton Group of Thedford, Ontario, by H. W. Shimer and A. W. Grabau, Bull. Geol. Soc. Am. Vol. 13, p. 149, 1901; Geology and Paleontology of Eighteen Mile Creek and the Lake Shore Sections of Erie County, by A. W. Grabau, Bull. Buffalo Soc. Nat. Sci. Vol. VI, 1899; A Study of the Fauna of the Hamilton Formation of the Cayuga Lake Section in Central New York, by H. F. Cleland, Bull. 206, U. S. Geological Survey, 1903.

---

* Bull. 206, U. S. G. S., p. 91.

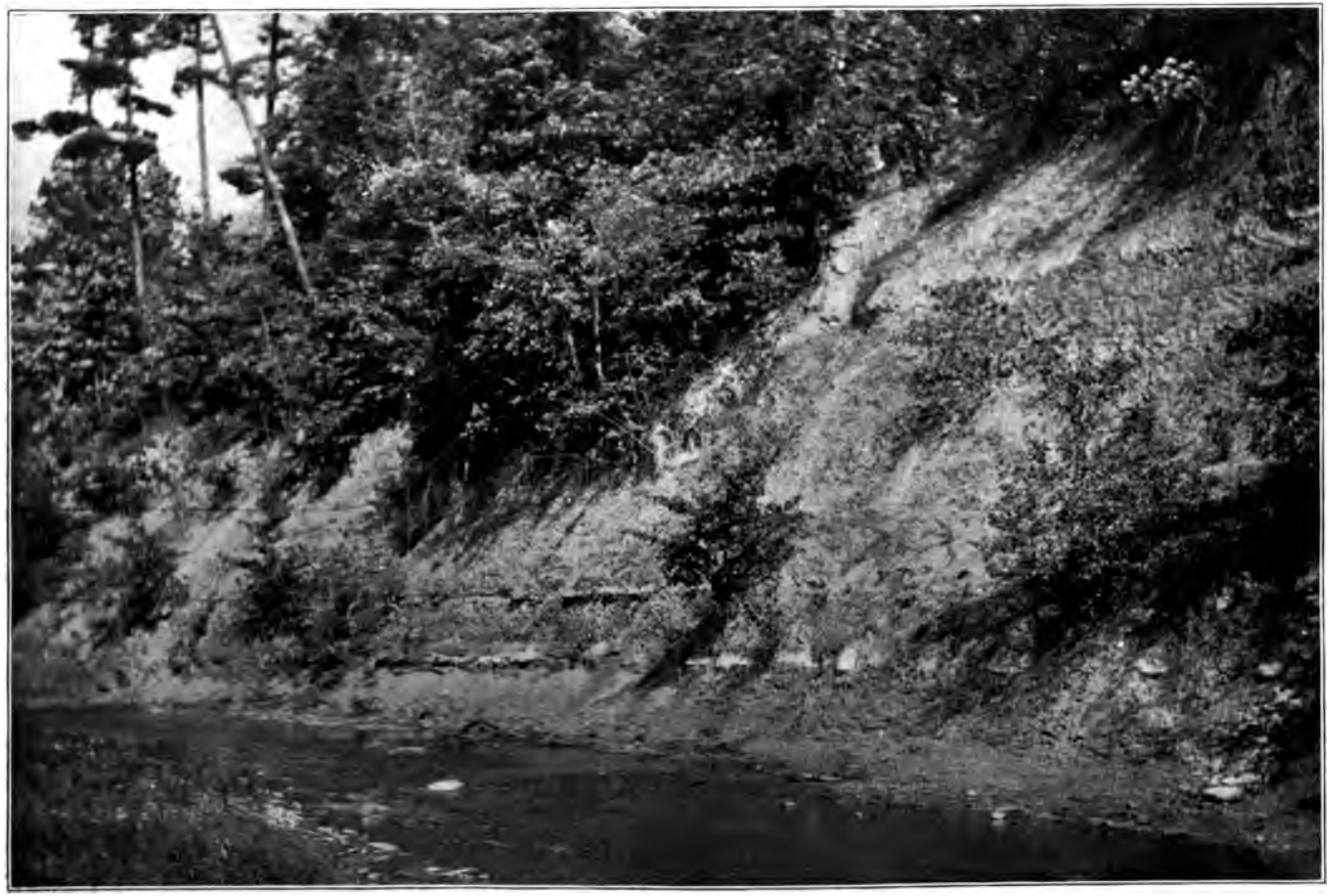
DISTRIBUTION OF SPECIES.

	Moscow.	B 4.	B 5.	B 6.	B 7.	B 8.	B 9.	Windom.	Thedford.	Eighteen Mile Creek.	Cayuga Lake.
PORIFERA.											
Astræospongia hamiltonensis *M. & W.*		1							M		
CŒLENTERATA.	4										
Alveolites goldfussi *Billings*	53	10				14			M		
Amplexus intermittens *Hall*	51							68		M	
A. hamiltoniae *Hall*						18	4	57		M	
A. yandelli *E. & H.*		1									
Aulopora serpens *Goldf.*		11	2			8		2	M	H	M–H
A. tubæformis *Goldf.*		1				2				H	
A. erecta *Rominger*		4				6					
A. sp.		10				6					
Blothrophyllum conatum *Hall*	3	36			3	24			M	M	
Ceratopora jacksoni *Grabau*		17				31		12		H	
Craspedophyllum archiaci *Billings*	12	163			4	141	2		E	E	M
C. subcæspitosum *Nich.*		64							M	E	
C. sp.		38				61					
Cyathophyllum gradatum *Hall*		11				7					
C. nanum *Hall*		6				49					
C. nepos *Hall*		4			1	5					
C. palum *Hall*		5				6					
C. perlamelosum *Hall*		3			1						
C. robustum *Hall*		22				3			M		
C. sp.	4										
Cystiphyllum americanum *E &H*	16					1				M	
C. conifolle *Hall*	48	24				4			M	M–H	
C. corrugatum *Hall*		3			2						
C. varians *Hall*	63	6			2	3					
Favosites arbuscula *Hall*	22	44			10	70					
F. argus *Hall*		4			7	13				H	M
F. billingsi *Rominger*		15			1	1			M	E	
F. clausus *Rominger*	23	136			4	32			M		
F. emmonsi *Rominger*	3	3			2	12	2				
F. hamiltoniæ *Hall*								3			
F. hemisphericus turbinatus *Billings*		19				4			EM		
F. nitella *Rominger*	13	65				7	1				
F. placenta *Rominger*		93			4	113			M		
F. tuberosa *Rominger*		4				2	1				
Heliophyllum arachne *Hall*	2										
H. confluens *Hall*							1				
H. dejener *Hall*		5			1	2					
H. halli *E. & H*	13	122			8	24	2		M	M–H	M–H
H. irregulare *Hall*		21				22					
H. juvene *Rominger*	1	48			5	44					
H. reflexum *Hall*		26				4					
Hadrophyllum woodi *Grabau*	5						1	10			

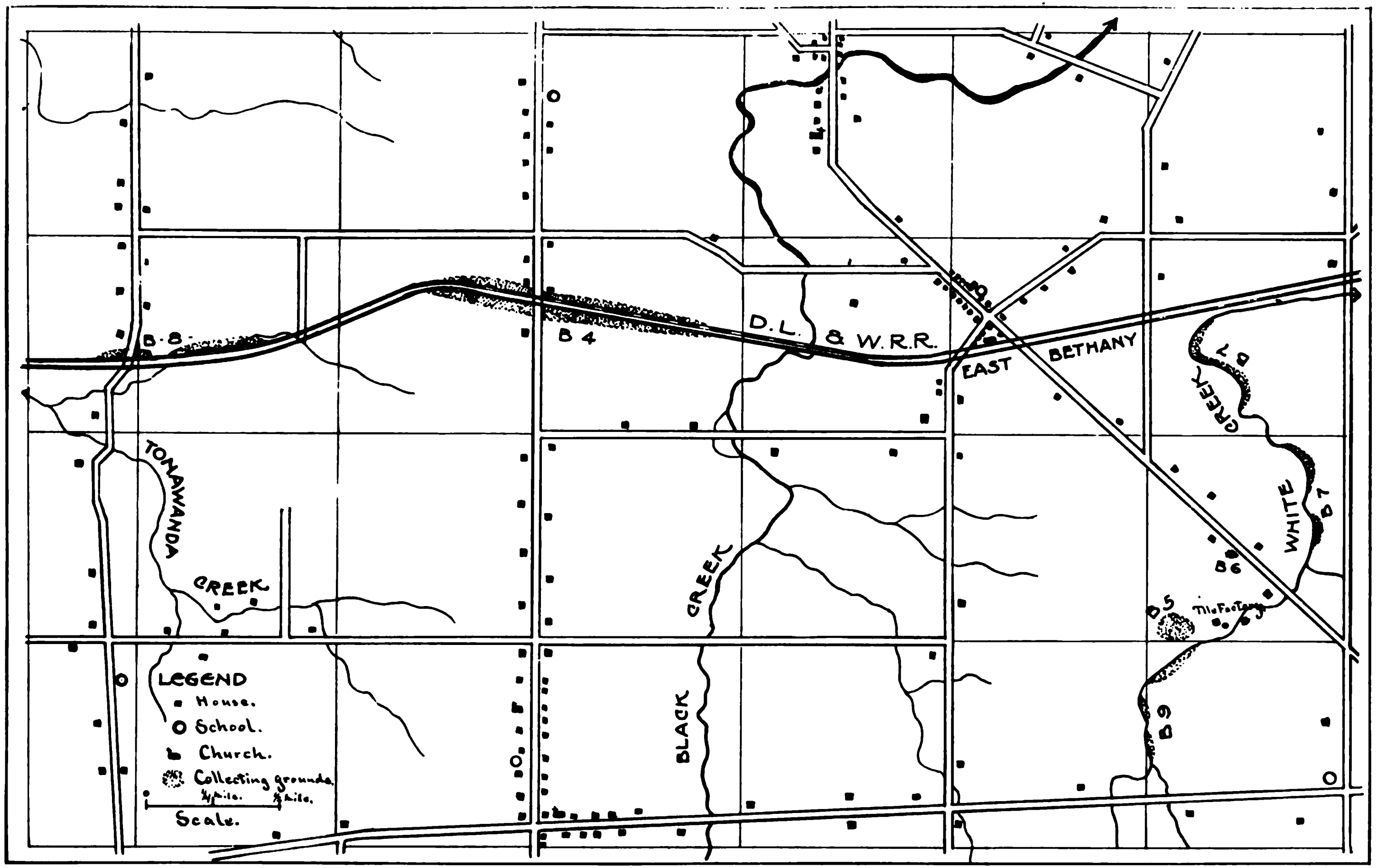
	Moscow.	B 4.	B 5.	B 6.	B 7.	B 8.	B 9.	Windom.	Thedford.	Eighteen Mile Creek.	Cayuga Lake.
CŒLENTERATA—Con.											
Lichenalia sp.	1										
Michelinia insignis *Rominger*		6			1	23					
Monilopora antiqua *Whitfield*		2							M		
Pleurodictyum dividua *Hall*		2				12					
P. stylopora *Eaton*	3		5		7	9	9	5		H	M–H
Streptelasma rectum *Hall*	28	11			6	4	3	30		M–H	M–H
S. ungula *Hall*	60	18		1	18	10		21		M	
Stromatopora sp.		8				9					
Syringopora sp.						2					
Trachypora limbata *Eaton*	3			2	5	77	1				
Zaphrentis exigua *Billings*		16				5					
Z. simplex *Hall*	14	30				10				ME	M
Z. sp.						2					
PELMATOZOA.											
Hypsocrinus fieldi *Spr. & Sl.*		1									
Ancyrocrinus bulbosus *Hall*					1	2		1	H	M–H	E
Codaster hindei *E. & C.*		1									
Pentremitidea sp.						1	1				
Crinoid plates		1				5					
Crinoid roots	2	1	9	1		10					
Crinoid stems	10		16			6	14	5			
Crinoid arms							1				
VERMES.											
Autodetus lindstromi *Clark*						1					
Cornulites hamiltoniæ *Grabau*						5	3				
Spirorbis angulatus *Hall*			26			5	10			H	H
S. omphaloides *Nichols*	1								M		
Worm teeth						2					
Fish bone								1			
BRYOZOA.											
Botryllopora socialis *Nich*							3		M	H	
Hederella canadensis *Nich*		4	40			6		1	M	H	M
H. cirrhosa *Hall*	4	2	14		1	14	18				
H. filliformis *Billings*			7						M	M	
Monotrypa fruticosa *Hall*	40									H	M–H
M. furcata *Hall*	30									M–H	
Stictopora incisurata *Hall*	1		14							EH	M
BRACHIOPODA.											
Ambocœlia umbonata *Conrad*	22					7	97	19	M	M–H	M–H
A. nana *Grabau*		10				13				H	
Athyris spiriferoides *Eaton*	28	50		2	22	90	13	106	M	M–H	M–H
A. fultonensis *Swallow*		2							H		
Atrypa reticularis *Linn*	30	103	1			72	15	14	M	M–H	M–H
A. spinosa *Hall*	16							3		M	
Camarotœchia billingsi *Hall*		6				14					
C. horsfordi *Hall*	21	8	12			11	18	1		M–H	ME
C. sappho *Hall*						10			M	EH	M–H
C. tethys *Billings*						17					
Chonetes coronatus *Conrad*	3	11	7			27	60	1		EH	M–H
C. lepidus *Hall*		1							M	M–H	M–H
C. mucronatus *Hall*	4	9			11	13	28	12		M–H	M–H
C. scitulus *Hall*					58	3	24	3	M–H	M–H	M–H
C. vicinus *Castelnau*	2		7						M–H	M–H	M
Cranæna romingeri *Hall*						16			M	H	

	Moscow.	B 4.	B 5.	B 6.	B 7.	B 8.	B 9.	Windom.	Thedford	Eighteen Mile Creek.	Cayuga Lake.
BRACHIOPODA—Con.											
Crania crenistriata *Hall*		4				1			M	H	
Craniella hamiltoniæ *Hall*		3	1			5	2	5	M	M-H	M-H
Cryptonella planirostris *Hall*		6				21	2			EH	H
C. rectirostris *Hall*	4	8				21				H	H
Cyclorhina nobilis *Hall*		1				1			M		
Cyrtina hamiltonensis *Hall*	3	52				76	7		M-H	M-H	M-H
C. hamiltonensis recta *Hall*		8				5			M	H	
Delthyris consobrina *d'Orb.*	13					2		13	M	M	M-H
D. sculptilis *Hall*	2	13				71		2	E	E	H
Eunella lincklæni *Hall*						9					M-H
Leiorhynchus dubium *Hall*						2				H	E
L. laura *Billings*	1	6				20			M	M-H	M-H
Lingula sp.	3			2		1					
Meristella barrisi *Hall*		6			1						
M. haskinsi *Hall*	1					4				E	EH
Nucleospira concinna *Hall*	2	40	76	17		101	13	3	M	M-H	M-H
Orthothetes arctostriatus *Hall*		2							M-H	M-H	M-H
O. chemungensis *Conrad*						2	2			M-H	M-H
Parazyga hirsuta *Hall*		30			1	121			M		
Pholidostrophia iowaensis *Owen*		93				48	1		M-H	EH	M-H
Productella spinulicosta *Hall*		5									M-H
Reticularia fimbriata *Conrad*		9				17	3				M-H
Rhipidomella leucosia *Hall*						32					
R. penelope *Hall*		56				44	11	5			M
R. vanuxemi *Hall*	46	147	2			220	24	32			M-H
Rœmerella grandis *Vanuxem*	1										
Spirifer acuminatus *Conrad*								1			
S. angustus *Hall*		3						2			
S. audaculus *Conrad*	47			8			6	46	E	M-H	M-H
S. audaculus macronotus *Hall*	2	20	1			45		6			M-H
S. divaricatus *Hall*		1			1	7			E		EH
S. granulosus *Conrad*	4	4				3	3	12		EH	M-H
S. granulosus clintoni *Hall*							3				M
S. marcyi *Hall*	3						6	1			M
S. pennatus *Atwater*	10	7	22	6	26	55	29	76	M-H	M-H	M-H
Stropheodonta concava *Hall*	7	3			4	5		2	M	EH	M
S. demissa *Conrad*		51				37		20	M-H	EH	H
S. inæquistriata *Conrad*	7	24			1	128	5	4	M	M-H	M-H
S. perplana *Conrad*	1	6				2		5	M	M-H	M-H
S. plicata *Hall*						5				H	
S. textilis *Hall*	1						1				
S. sp.						9	3				
Terebratula sp.		9									
Tropidoleptus carinatus *Conrad*	23	6	106			6	68	29	E	HE	M-H
PELECYPODA											
Actinopteria boydi *Conrad*	4			1		1			H	H	M-H
A. decussata *Hall*		2									ME
Aviculopecten princeps *Conrad*	2								M	EH	M-H
Conocardium eboraceum *Hall*								1			
Cypricardella bellistriata *Conrad*		1								EH	M-H
Elymella nuculoides *Hall*						1					M
Goniophora hamiltonensis *Hall*							1				M-H
Grammysia arcuata *Conrad*	3									H	M-H
Leiopteria Conradi *Hall*	3										M-H
Modiomorpha concentrica *Conrad*			1							H	M-H

	Moscow.	B 4.	B 5.	B 6.	B 7.	B 8.	B 9.	Windom.	Thedford.	Eighteen Mile Creek.	Cayuga Lake.
PELECYPODA —Con.											
Nucula sp.	1				1						
Nuculites nyssa *Hall*			1							H	
Orthonota undulata *Conrad*	1		1								M–H
Palæoneilo constricta *Conrad*	3							1		H	M–H
Pholadella radiata *Conrad*	1									H	M–H
Plethomystus oviformis *Conrad*.										E	M–H
Pterinopectin undosus *Hall*	3									H	M–H
Sphenotus truncatus *Conrad*	1										
Tellinopsis subemarginatus *Conrad*	1									H	M–H
GASTROPODA											
Bellerophon sp.								1			
Platyceras attenuatum *Hall*						18		1		EH	
P. bucculentum *Hall*						5			H	E	M
P. carinatum *Hall*		3				14	1			EH	M
P. conicum *Hall*						2					E
P. dumosum rarispinum *Hall*						10					
P. echinatum *Hall*		2									
P. erectum *Hall*	2	1	2			37		2		H	M–H
P. symmetricum *Hall*	1					4				H	
P. thetis *Hall*				2		8			H	H	
Platyostoma lineatum *Conrad*	4	16			5	155	4	1	M–H	M–H	M
P. lineatum emarginatum *Grab*						9				H	
P. turbinatum *Hall*						17			H		
Pleurotomaria itys *Hall*					3					H	M–H
P. sp.								6			
PTEROPODA											
Styliolina fissurella *Hall*		4							M	M–H	M–H
CEPHALOPODA											
Orthoceras crotalum *Hall*					1						M–H
TRILOBITA											
Dalmanites boothi *Green*	15	1							M	M–H	M–H
D. boothi calletelles *Green*	1									EH	M
Homalonotus dekayi *Green*	3						1			H	EH
Phacops rana *Green*	32	29		4	1	104	3	19	M–H	M–H	M–H
Prœtus rowi *Green*		1				2				H	E
P. curvimarginatus *Hall*		1							H	H	



Typical outcrop of the Moscow Shale, Moscow, Livingston County, New York.



Map of a portion of the town of Bethany, New York, showing collecting grounds.

FIELD COLUMBIAN MUSEUM.
PUBLICATION NO. 114.
GEOLOGICAL SERIES. VOL. II, NO. 9

HYPSOCRINUS, A NEW GENUS OF CRINOIDS FROM THE DEVONIAN.

BY
FRANK SPRINGER
AND
ARTHUR WARE SLOCOM,
Assistant in Paleontology

OLIVER CUMMINGS FARRINGTON, Ph. D.
Curator, Department of Geology.

CHICAGO, U. S. A.
June 1, 1906.

HYPSOCRINUS, A NEW GENUS OF CRINOIDS FROM THE DEVONIAN.

BY FRANK SPRINGER AND ARTHUR W. SLOCOM.

Among the fossils collected by the junior author from the Hamilton shales, at Bethany, New York, was a Crinoid, which was found in the railway cut about one and one half miles west of the station of East Bethany. This locality is more fully described in another paper.* As this Crinoid, a single specimen of which was found, did not seem referable to any known genus, it was submitted to the senior author for his opinion, and as a result of his examination, it was deemed advisable to describe and illustrate it under our joint names. A very pronounced asymmetry, marked by a very unequal gibbosity at one side, induced at first the suspicion that the specimen might be abnormal. But it was found on examination to be in a remarkably fine state of preservation, the surface being in perfect condition, free from matrix, so as to show all its characters most clearly, without any artificial cleaning. Every suture was distinct and well marked, so there could be no doubt of the exact arrangement of the calyx plates. This being so, the question arose, if it is an abnormal specimen, to what species or genus does it, or might it, belong? No answer could be found to this question, and we have therefore concluded that the only proper course is to propose a new genus for its reception. The specimen is unique, nothing at all approaching it having ever been found, to the knowledge of the authors, in the Hamilton collections that have been made at various localities in this country, or in equivalent rocks in Europe. We hope that collectors will be on the look-out for it hereafter, and that if other specimens should come to light, we may be informed of the fact.

HYPSOCRINUS gen. nov.

(ὕψι, high, κρίνον, lily.)

An inadunate, monocyclic Crinoid, with two or more compound radials. Basals five. Radials five, of which the right posterior,

---

* Field Columbian Museum Publication, Geological series, Vol. II, p. 258.

right anterior, and perhaps anterior, are compound, — the first two bisected transversely, and the last, if at all, obliquely. No anal plate in the dorsal cup, but the lower segment of the right posterior radial probably is the radianal. Radial facets shallow, concave, filling the greater part, but not all, of the distal face of the radials. Arms simple, non-pinnulate. Tegmen unknown.

This genus belongs to a little group of irregular, Inadunate Crinoids, represented by *Pisocrinus* in the Silurian, and *Triacrinus*, *Haplocrinus* and *Calycanthocrinus* in the Devonian, having a monocyclic base, and one or more compound radials divided by transverse bisection. They belong to the group called Larviformia by Wachsmuth and Springer, Larvata by Jaekel, and Monocyclica Inadunata by Bather. Our genus differs from *Pisocrinus*, *Triacrinus*, and *Haplocrinus* in the character of the radial facets, which, instead of occupying a small, squarely mortised socket in the middle of the plate, are broad, shallow, and fill a large part of the distal face of the radial. This alone, and there are others beside, is a good generic distinction. *Calycanthocrinus* has somewhat similar radial facets, but represents a modification on another line, having several small supplementary arm-bearing radials in addition to the regular five, perhaps produced by a vertical bisection at the corners of the larger radials.

The genus *Phimocrinus* Schultze, from the Devonian of the Eifel, and elsewhere in Europe, is perhaps the one with which the most interesting comparison may be made. It is of similar elevated form, with five elongate basals, and five elongate, arm-bearing radials, which, as defined by Schultze, are regular in form.[*] The genus has been classed with the Symbathocrinidæ. In 1882, M. D. Oehlert[†] described and figured from the Lower Devonian of Sable, Department of La Sarthe, a new species, *Phimocrinus jouberti*, having the regular five basals, and five equal radials of the genus. But in the description the author states that he observed, on the two radials to the right of the anal side, and the second radial to the left of it (i. e., the r. post., r. ant., and l. ant. RR), and at about two-thirds of their height, a light and very distinct transverse groove, dividing these plates into two unequal parts; and he expresses the opinion that this groove marks the anchylosis of two pieces which were separate in the young stage. These transverse marks are faintly shown on Oehlert's figures (Pl. VIII, Fig. 1, 1a, 1b), but there are in the collection of the senior author, two specimens of this species, from the same locality as Oehlert's, which show them very plainly, not as actual sutures, but rather as lines of anchylosis. So it is evidently a constant character. The transverse bisection of the radials by the sutures represented by these lines would produce compound radials in the same rays in which they occur in *Haplocrinus*, *Heterocrinus*, and similar forms. This species, therefore, represents a form which in its younger stage would have fallen into the same group of irregular crinoids as our genus, but in which, by growth during life, the compound radials were eliminated, and the Crinoid modified into a regular form. *Phimocrinus* has straight radial facets, filling the entire distal face of the radials, and the arms articulate on a linear hinge line.

---

[*] Mon. Echin. d. Eifel, Kais. [illegible]

[†] Bull. Soc. Géol. de France, [illegible] X, p. [illegible]

HYPSOCRINUS FIELDI sp. nov. Pl. LXXXI, Figs. 1–6.

Calyx elongate, cylindrical, slightly expanding to the arm bases. Base truncate; basal facet broad, slightly concave, entirely filled by the column; axial canal stellate or pentagonal, interradial in position. Basals very elongate, forming two-fifths to half the height of the cup. Radials, three large and two small, all arm-bearing; the two smaller ones short, wider than high, separated from the basals by three much more elongate infer-radials, one of which is directly beneath the right posterior radial, and represents the radianal; the other two are for the most part directly under the right anterior radial, whose lower margin meets them by an obtuse angle, but in part obliquely under the left lower corner of the anterior radial, meeting it by a curved suture; the other three radials are large and elongate plates. Arm facets very shallow, curved, not entirely filling the distal face of the radials, but leaving short, sloping shoulders between, which are rounded off exteriorly, but probably formed a support for oral plates in the tegmen. Arms simple, uniserial, tapering rapidly, and doubtless very short. No trace of a dorsal canal in radials or brachials. Anal structures and tegmen unknown. Surface smooth; calyx plates slightly rounded, and sutures distinct. Stem unknown; but it was large at the proximal end, as the radiate markings of its articulation are visible to the edge of the basal facet.

Horizon and *Locality*: Devonian; Hamilton group. Found near East Bethany, New York.

The specific name is in memory of Marshall Field, the founder of the Field Columbian Museum, where the type specimen is deposited.

Remarks. In the foregoing description we have found it necessary to guard against the insertion of some details, which are apparent enough in the figures, but which may possibly be due to individual variation, or abnormal development. The form and distribution of the compound radials differ from those observed in any of the other genera of this group in the presence of two large plates underneath the superior part of one radial, so that we have apparently three infer-radials, with only two super-radials. The space occupied by one of these in the calyx wall is enough to account for the lateral bulging which gives its unsymmetrical form. Having but the one specimen, we cannot tell whether this feature is constant or not, and the specific and generic definitions do not depend upon it. As asymmetry is a frequent character in this group, however, there is no inherent improbability that the same construction will be seen in other specimens, if such are found. We give for comparison diagrams of *Pisocrinus* and *Haplocrinus*, the two genera nearest related to this structurally, (Pl. LXXXI, Figs. 7 and 8).

Pisocrinus has two short super-radials, which rest upon one large infer-radial in common. *Haplocrinus* has three short super-radials each with its corresponding infer-radial. Our crinoid has two short super-radials, one connected by a transverse suture with its infer-radial, while the other is angular below, and meets the upper sloping faces of the two infer-radials. If now we examine the diagram of *Haplocrinus* (Fig. 8) we will see that the right anterior super-radial is angular below, and meets by one side an upper sloping face of the infer-radial below it, and by the other a corresponding sloping face of the anterior radial, which is one of the two largest plates in the calyx. If a portion of this anterior radial were cut off by a curving suture, as indicated by the dotted line in the diagram, it would give a construction substantially the same as that of our genus in this respect, viz: two short super-radials supported by three infer-radials. In view of the other pronounced differences in the composition of the calyx, such a modification of the radial structure of *Haplocrinus* may well have become constant in our form.

A few of the arm plates have fallen in over the summit of the cup, and are thus preserved. They are restored to position in the diagram (Fig. 6). The first brachial of the left posterior ray is wanting, but its position is indicated by dotted lines. It will be observed that the right posterior radial has a smaller facet, and bears a smaller arm than the others. It is probable that the arms were very short, with but few more brachials than remain in the right anterior ray.

We cannot be absolutely certain that the orientation of the calyx here given is correct, as we do not know the position of the anus. It agrees with what we know of the relative positions of the compound radials in *Pisocrinus* and *Haplocrinus*, and we see no reason for thinking any other arrangement preferable. A peculiar fact, which we have also omitted from the specific description, is that the posterior basal is much larger than any of the others, and is enlarged in such a way as to be actually radial in position, instead of inter-radial, as basals normally are.

We have not been able to ascertain anything of the construction of the tegmen. We attempted to remove some of the overlying brachial plates for that purpose, but they were found to be so firmly cemented by pressure, that the only result was fracture of these plates along the cleavage planes of the calcite, without revealing the structures underneath. The tegmen is clearly not an elevated pyramid like that of *Haplocrinus*, but beyond this, no opinion can be ventured with our present knowledge.

EXPLANATION OF PLATE LXXXI.

HYPSOCRINUS FIELDI, n. sp.

Fig. 1. Lateral view of calyx, from right posterior ray.

" 2. Same, from right anterior ray.

" 3. Same, from anterior ray.

" 4. Same, from left anterior ray.

" 5. Same, from left posterior ray.

In these figures the remains of the brachial plates are seen lying upon the summit of the calyx in an apparently confused mass, but they are mostly in their proper relative positions, and can with reasonable certainty be restored. All figures ×⅔.

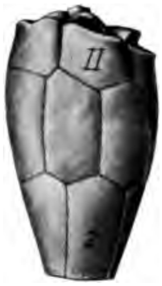
" 6. Diagrammatic view of calyx plates, with brachials arranged in natural order; the first brachial of the left posterior ray is missing, but is restored in dotted lines. The rays are numbered from the right posterior toward the right, and for convenience of comparison, these numbers, — as well as a series of numbers for the basals, — are carried into the accompanying figures.

" 7. Diagram of calyx of *Pisocrinus* (after Bather).

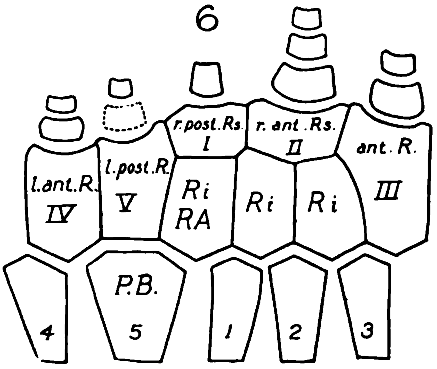
" 8. Diagram of calyx of *Haplocrinus* (after Bather).

(Explanation of lettering on figures: RA=radianal: Rs=super-radial ; Ri=infer-radial : PB=posterior basal : X=anal plate.)

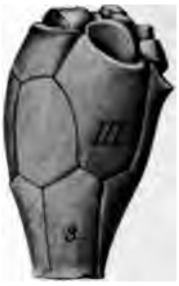
2


II
2

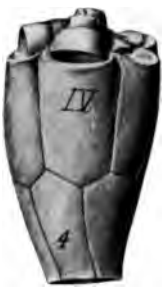
6


l.ant.R.
IV
l.post.R.
V
r.post.Rs.
I
Ri
RA
r.ant.Rs.
II
Ri
Ri
ant.R.
III
4
P.B.
5
1
2
3

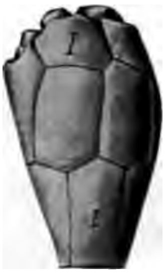
3


III
3

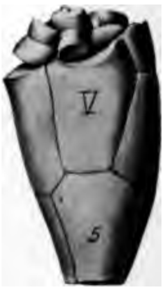
4


IV
4

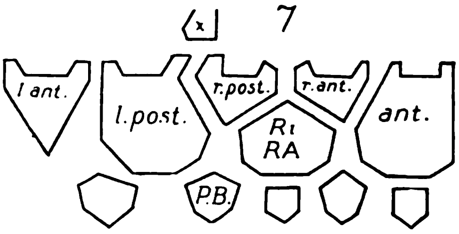
1


I
1

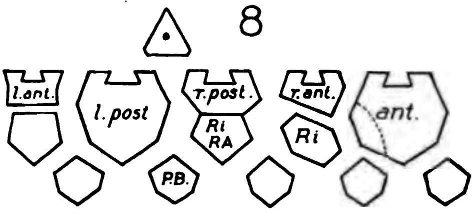
5


V
5

7


x
l ant.
l.post.
r.post.
r.ant.
Ri
RA
ant.
P.B.

8


l.ant.
l.post
r.post.
Ri
RA
r.ant.
Ri
ant.
P.B.

FIELD COLUMBIAN MUSEUM.
PUBLICATION 123.
GEOLOGICAL SERIES. VOL. II, NO. 10.

NEW CRINOIDS FROM THE CHICAGO AREA.

BY

ARTHUR WARE SLOCOM,
Assistant Curator, Section of Invertebrate Paleontology.

OLIVER CUMMINGS FARRINGTON,
Curator, Department of Geology.

CHICAGO, U. S. A.
October 31, 1907.

NEW CRINOIDS FROM THE CHICAGO AREA.

BY ARTHUR WARE SLOCOM

In the fall of 1905 the attention of the writer was called to the fact that fossils were being found at a quarry operated by the Illinois Steel Company for limestone for flux, at Romeo, Illinois. Upon visiting the quarry it was found that not only was the limestone itself fossilferous, but that silicified fossils were abundant near the bottom of large clay pockets which were exposed at various places in the quarry. These clay pockets occupy large, irregular shaped cavities in the limestone. The larger ones are 15 or more feet deep and their width is often greater than their depth. In some instances several are connected, their connections following the jointing of the limestone. These cavities, or "pot-holes" as they are sometimes called, often associated with furrows, are to be seen in many places along the Chicago Drainage Canal where the surface of the rock is exposed. The cavities vary in size from a fraction of an inch in depth to those mentioned above. These cavities or pot-holes must have been in part subjected to the action of running water since their sides are smooth. They are frequently broader at the base than above and may even be cone-shaped, with the apex of the cone above. Their filling is for the most part a blue homogeneous clay. This contains small silicified fossils of Niagaran age, small, modern, fresh-water shells and fragments of pyritized and charred wood. No large boulders or pebbles occur in the clay, although these frequently form a capping of the pockets. The question of the origin of the filling of the pockets is a matter of no little interest. The clay could not be of preglacial origin because of its content of wood and modern shells. If of postglacial origin, the presence of the Niagaran fossils is difficult to account for. A wall of the quarry showing typical pockets is represented in Plate LXXXII. A single one in more detail is represented in Plate LXXXIII.

During the fall of 1905 and the spring and summer of the following year, over 400 fossils representing 38 species were collected by the writer from these clay pockets. These fossils were divided as follows:

Corals	293 specimens,	15 species;
Sponges	20 specimens,	3 species;
Bryozoans	12 specimens,	4 species;

Crinoids	21 specimens,	7 species;
Brachiopods	96 specimens,	9 species;
Trilobite	1 fragment.	

Of this material the corals, sponges and crinoids showed a great similarity to those found at St. Paul, Indiana, and Perry county, Tennessee, and a number of species described from those localities were recognized. It was found that the manner of preservation of the clay pocket fossils differed from that usual to those of the limestones of the Chicago Area in that the latter are natural casts and molds, while the clay-pocket fossils are silicified. Search in the surrounding limestone at Romeo failed to show similarly preserved fossils in place there and only a few of the clay-pocket species were discovered. The spoil heaps of the Chicago Drainage Canal were then studied and near Lemont, Illinois, the species found in the clay began to appear, until all the brachiopods and part of the corals were found. Many of these were in a similar state of preservation to those of the clay pockets. Of the seven species of crinoids occurring in the clay three were found in the Lemont limestone and three more were represented by species of the same genera. Over 400 fossils, representing 76 species, were collected at this locality, divided as follows:

Sponges	3 specimens,	1 species;
Corals	40 specimens,	6 species;
Cystoids	62 specimens,	6 species;
Crinoids	149 specimens,	32 species;
Bryozoans	10 specimens,	6 species;
Brachiopods	62 specimens,	11 species;
Mulluscs	9 specimens,	5 species;
Trilobites	82 specimens,	9 species;

The finding of these silicified corals and brachiopods at Lemont identical with those occurring in the clay pockets, left little room for doubt that the clay and fossils found in it were residual from the Niagaran limestone, and that they had been transported to Romeo from the Lemont Area. The Romeo quarry is distant about five miles in a southwesterly direction from the point near Lemont where the corresponding fossils were found. Both localities are in the valley known as the Chicago Outlet, through which the waters which occupied the basin of Lake Michigan at the close of the glacial period discharged into the Mississippi River. The flow of these waters would have been sufficient to transport material like that described from Lemont to Romeo, although the period and exact circumstances of this deposition have not as yet been determined. The silt-like nature of the deposit in the clay pockets shows that it occurred in quiet waters.

Among the crinoids collected in this work several proved to be either hitherto undescribed or new to the Area. Of these five had been described from other localities and nine were new species. Of three species previously described by other authors, additional characters, which are here given, were obtained from specimens found by the writer. The nine new species are here described and five species previously described from other localities are here re-described. A total of seventeen species of crinoids is therefore described in the present paper.

CLASSIFICATION AND TERMINOLOGY

The classification here used is that prepared by Wachsmuth and Springer and is substantially that given in the English edition of Zittel's Text-book of Paleontology. The terminology of Wachsmuth and Springer is also adhered to. It may be briefly stated as follows:

Crinoid: A normal crinoid consists of a crown attached by its dorsal extremity or base to a stem or column which is fixed to some solid body by a root.

Crown: All of the crinoid above the stem. It includes the calyx and the arms.

Calyx: The body of the crinoid without the free arms or stem. It incudes the dorsal cup and ventral disc or tegmen, and within it are enclosed the more important organs of the body.

Dorsal Cup: That part of the calyx below the point of attachment of the free arms. It is usually more or less cup-shaped and is composed of two or more rows of plates having a more or less complete pentamerous symmetry.

Ventral Disc, Tegmen, Dome, etc.: That part of the calyx above the point of attachment of the free arms. It is made up of plates more or less regularly arranged and contains the mouth and usually the anal opening.

Base: That part of the dorsal cup lying between the radial plates and the stem. It consists of a single row of plates, the basals, in a monocyclic base, and of two rows of plates, the basals and infrabasals, in a dicyclic base.

Rays or *Brachials*: The series of plates which rests upon the basals and extends up to and forms the arms. The first plate of the series is always a part of the dorsal cup, the others may or may not be a part of the cup. There are five of these rays, except in the Zophocrinidæ, and they are designated as follows: (Figs. 1 and 2) (1) *right posterior ray*, (2) *right anterior ray*, (3) *anterior ray*, (4) *left anterior ray*, and (5) *left posterior ray*.

Interbrachial areas (I Br.*): The plates in camerate crinoids situated between the rays.

Anal or *posterior interradius* (X. a. a.): The area situated between the right and left posterior rays and leading up to the anal opening.

Basals (B): The circle of plates directly below the radials and alternating with them. In a monocyclic base they join the column.

Infrabasals (I B): The first row of plates in a dicyclic base. They separate the basals from the column and are radial in position.

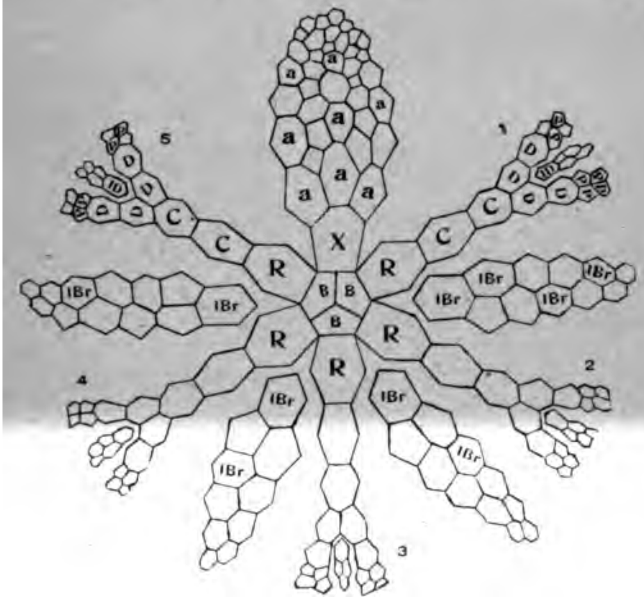


Fig. 1. Diagram of a Monocyclic, Camerate Crinoid.

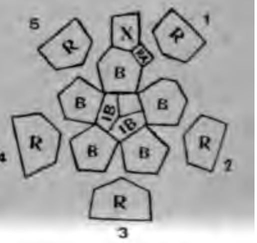


Fig. 2. Diagram of a Dicyclic Crinoid.

Radials (R): The first plate of each ray, usually resting on the basals. In some families part of the radials are divided horizontally. The parts of these plates are called *superradials* (Rs) and *inferradials* (Ri), respectively.

Costals (C): Those plates of each ray extending from the radials, on which they rest, up to the first bifurcation.

Distichals (D): All plates of each ray between the first and second bifurcation.

Palmers (P): All plates of each ray between the second and third bifurcation. Any plates of a higher order than these are called *post-palmers*.

---

* The letters in parenthesis refer to those of Figs. 1 and 2.

Interdistichals (I D): Any plates situated between the distichals.

Anal Plate (X): First plate of the anal interradius. It often rests upon the posterior basal and is in line with radials or nearly so.

Interbrachials or *interradials* (I Br): Any plates of the interbrachial areas.

Radianal (RA): A plate resting within the angle formed by two basals and below the right posterior radial plate. It joins the anal plate on the left and occupies the position of an inferradial.

Distal: Farthest from the stem.

Proximal: Nearest to the stem.

Lateral: Pertaining to the side.

Authors differ widely in the use of the terms "mold," "cast" and "impression," but as used in this paper they may be defined as follows:

Natural mold: A matrix or cavity in the rock, formed, by natural causes, around an organism when the rock was plastic. The external form of the organism is thus preserved.

Natural cast: The rock filling of the internal or visceral cavity of an organism, the shell of the organism having served as a mold. In many cases (see Plate LXXXIV, Figs, 3 and 10) the shell is afterwards dissolved out, leaving the mold and cast in position. In such cases the space between the two indicates the thickness of the shell.

Impression: An artificial cast, made in a natural mold, which shows the external features of the organism.

In the following descriptions three materials are referred to as being used for making impressions, viz.: plaster, roller composition, referred to as "composition," and vulcanized rubber, referred to as "rubber." The methods of making impressions from the two latter substances have been previously described by the writer.* In addition to the details there given it may be remarked that in many cases the shape and position of the mold in the rock is such that it is difficult to keep the rubber in place while vulcanizing. In such cases it is necessary to build a retaining wall of plaster, or to cement a metal ring around the opening of the mold; this prevents the rubber from spreading when the pressure is applied with the clamp, and a perfect impression is assured.

---

* Science, 1907, N. S. Vol. XXV, p. 591.

DESCRIPTION OF GENERA AND SPECIES.

Order I. LARVIFORMIA.

Family PISOCRINIDÆ.

PISOCRINUS De Konik.

No members of this genus have hitherto been reported from this Area. Representatives of three species, *P. benedicti*, *P. gemmiformis* and *P. quinquelobus* were found by the writer. The generic characters are as follows: Calyx small, globular, subconical or subcylindrical. Facets for the attachment of the arms wide, angular and projecting limbs of the radials short.

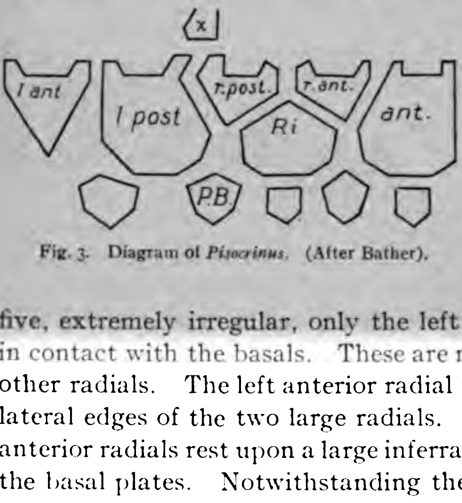


Fig. 3. Diagram of *Pisocrinus*. (After Bather).

Basals five, forming a triangle. The three plates situated at the angles larger than the other two. Radials five, extremely irregular, only the left posterior and anterior radials in contact with the basals. These are more than twice the size of the other radials. The left anterior radial is angular below, resting on the lateral edges of the two large radials. The right posterior and right anterior radials rest upon a large inferradial which separates them from the basal plates. Notwithstanding the great difference in size of the radials, their distal edges are about equal. Anal plate rests on the processes of the posterior radials.

Arms neither branched nor pinnulate.

PISOCRINUS GEMMIFORMIS S. A. Miller, Plate LXXXIV, Figs. 1–4.

1879. *P. gemmiformis* S. A. M., Jour. Cincin. Soc. Nat. Hist. Vol. 2, p. 113, Pl. 9, Figs. 6 a-c, Osgood, Ind.

1886. *P. gemmiformis* Wachsmuth & Springer, Rev. Palæocr. Pt. III, p. 184.

1892. *P. gemmiformis* S. A. M., 17th Rept. Geol. Surv. Ind. p. 636, Pl. VI, Figs. 10–12, Madison, Ind.

Calyx globular, depressed at the base: plates thick, sutures indistinct, surface smooth or finely granular.

Basal plates five, forming a nearly equilateral triangle and curving into the basal cavity. The three plates at the angles are larger than the other two. The basal triangle is followed by three large plates which comprise the principal part of the calyx. These are the anterior and left posterior radials and an inferradial plate. The left posterior radial rests upon two basals, the other two plates rest upon three. The other three radials are small, angular below and are not in contact with the basals; the left anterior radial rests upon the sloping sides of the adjoining radials, and the right posterior and right anterior radials each rest, one side upon the inferradial and one side upon the adjoining radial. The distal edges of the radials are provided with short processes at their juncture with the lateral edges which form a wide, shallow, angular excavation for the attachment of the arms.

Arms not preserved.

Owing to the thickness of the plates, the natural casts of this genus bear little resemblance to the exterior of the calyces. The natural casts of this species are in the form of a triangular pyramid, truncated by a cylinder. The base of the pyramid is nearly flat and is formed by the inner surfaces of the basal plates. One face of the pyramid is formed by the inferradial plate and the other two by the lower part of the large radials. The cylinder is formed by the three small radials together with the upper part of the two larger ones.

The distinguishing characteristics of the exterior of the calyx of this species are its globular form, with its depressed base, gradually curving into the facet for the attachment of the stem. The casts are distinguished by the triangular pyramid at its base.

Locality: This species is comparatively abundant in the clay pockets in the limestone at Romeo, Illinois, where it occurs as silicified specimens which appear to be identical with those of the type locality. In the spoil heaps along the Chicago Drainage Canal near Lemont, Illinois, it is one of the most abundant crinoids in the form of natural molds and casts, and a single silicified specimen was found there.

PISOCRINUS BENEDICTI S. A. Miller, Plate LXXXIV, Figures 8–11.

1892. *P. benedicti* S. A. M., 17th Rept. Geol. Surv. Ind., p. 639, Pl. VI, Figs. 3–16.

Calyx deeply cup-shaped, moderately expanding to the upper third, rounded at the base and slightly constricted at the top; plates thick, surface smooth or finely granular.

The plates of the calyx are the same in number and position as in *P. gemmiformis*, but the basals are larger than in that species, so as to be visible in a side view of the calyx, and the two large radials and the inferradials are longer in proportion to their width, making the calyx higher than wide. The rounder base is provided with a deep basal cavity whose sides are subparallel.

The natural casts are subcylindrical, moderately expanding to the arm bases. The base is flat, having three slight protuberances which give it a subtriangular appearance from below.

The specimens here described appear to be more cup-shaped than Miller's original figures indicate, and no mention is made by him of the abrupt margin of the basal cavity. Examination of several hundred specimens of this species, from the type locality, shows these features to be characteristic and those which most easily distinguish this species from *P. gemmiformis*.

Locality: The specimens (Mus. No. P 8481), consisting of natural molds and casts on which the above description is based, were collected by the writer in the spoil heaps of the Chicago Drainage Canal near Lemont, Illinois. A single incomplete individual from the clay pockets at Romeo, Illinois, is doubtfully referred to this species.

PISOCRINUS QUINQUELOBUS Bather, Plate LXXXIV, Figures 5–7.

1893. P. *quinquelobus* Bather, Crinoidea of Gotland, Part I, p. 27.
1895. *P. milligani* Miller & Gurley, Bull. 7 Ills. St. Mus. p. 80, Pl. V, Figs. 27, 28.
1896. *P. quinquelobus* Bather, Am. Geol., Vol. XVII, p. 184.

Bather's description is as follows: "Dorsal cup low; pentagonal as seen from ventral surface, the angles of the pentagon being radial in position; the radial facets are very narrow, the radial processes correspondingly broad, forming the concave sides of the pentagon; basals hidden in the concavity of the stem." To which may be added: surface of plates smooth; sutures very obscure, only visible with the aid of a magnifier; stem round. The form and arrangement of the plates is similar to the two preceding species. No plates of the ventral disc present.

The species is closely related to *P. gorbyi* S. A. M.,* but is distinguished from that species by its shorter cup and the position of the basal plates, which in *P. gorbyi* are visible from a side view and in this species are concealed in the basal cavity.

Locality: The species is represented in the collections of this Museum by four specimens, P 8414 and P 8827, which were collected by the writer in the clay pockets of the Niagaran limestone at Romeo, Illinois. These specimens are silicified and in a good state of preservation. There seems to be no reason to doubt that they are specifically identical with the specimens from Tennessee on which the original description was based.

---

* 17th Rept. Geol. Ind., p. 640, Pl. VI, Figs. 17-20.

Family STEPHANOCRINIDÆ.

STEPHANOCRINUS Conrad.

Only one species of this genus has heretofore been recognized in the Chicago Area. Two new species have been collected by the writer and are here described. The generic characters are as follows: Basals three, about equal in size, two pentangular, one quadrangular. Radials five, equal, resembling the forked plates of some Blastoids. These prongs form interradial processes, and between them are situated the ambulacral grooves leading to the arms, which rise from a single axillary costal plate situated at the end of the sinus. Oral plates five, interradial in position and forming most of the ventral disc. They are not visible in a side view of the calyx. They join the inner surface of the radial plates and extend to the top of the interradial processes. Their lateral edges are in contact below the ambulacral grooves, but a space is left for the mouth at the center of the ventral disc. The anus is situated between the posterior oral plate and the adjoining process.

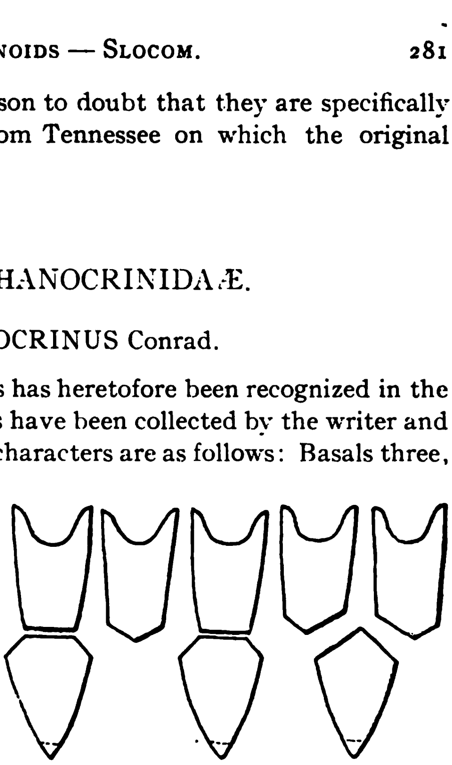


Fig. 4. Diagram of *Stephanocrinus*.

This genus has been referred to the Cystoids and Blastoids by some writers, and while it undoubtedly has some characters similar to both it has been shown to be a Crinoid by Wachsmuth and Springer on account of its brachial plates.

Stephanocrinus obconicus sp. nov. Plate LXXXIV, Figs. 12, 13.

The dorsal cup is obconical, truncated at the base, sides slightly convex, forming an angle of about 30 degrees. The surface of the plates is apparently smooth or finely granulose, following the curve of the calyx except near the proximal end of the basal plates, where they develop a median ridge giving a triangular form to the base. This ridge is most prominent at the base and rapidly diminishes, disappearing altogether before the center of the plate is reached. Sutures obscure, not marked by grooves.

Basal plates three, about equal in size. Two are pentangular and one is quadrangular. Together they form an obconical cup comprising about half the height of the calyx, triangular at the base and circular at the top. There is a slight circular depression in the center of the base for the reception of the column. Radial plates five, equal in size with the lateral edges produced into interradial processes. Height, aside from the processes, about equal to that of the basals. The characters of the vault are quite obscure, but appear to correspond with the description of the genus.

This species is based on a single silicified specimen (Mus. No. P 8416) in a fairly good state of preservation. Its obconical form renders it so unlike all other species of the genus that comparison with them seems to be superfluous. The following measurements, in millimeters, taken from the type specimen, may be of use for comparison in case other specimens are found.

Diameter at base,	2.3	mm
Diameter at top of basals,	5.5	"
Diameter at top of calyx,	6.4	"
Height of radials aside from spines,	4.6	"
Height of basals,	5.0	"
Height of calyx,	9.6	"
Length of spines,	1.0	"

Locality: Collected by the writer in the fall of 1905 in the clay pockets of the Niagaran limestone at Romeo, Illinois.

STEPHANOCRINUS SKIFFI, sp. nov. Plate LXXXIV, Figures 16–20.

The calyx has a small triangular base. It expands rapidly to the top of the basals and moderately from that point on. The distal edges of the radial plates are excavated for the reception of the arms, thus forming five interradial processes. The plates of the dorsal cup are ornamented with a series of acute prominent striae. These striae are oblique at and below the upper lateral angles of the radials, longitudinal on the middle of the radials and basals and transverse on the lower part of the basals. Sutures are obscure and do not interrupt the striae.

Basal plates three, about equal in size, one quadrangular, two pentangular. Together they form a funnel-shaped cup, triangular at the base and expanding very rapidly to the top. An acute angular ridge extends from the base to the center of each plate where it becomes lost in the longitudinal striae. The basal cup comprises about half the height of the calyx. Radials five, equal, sides slightly converging towards the base; moderately convex longitudinally, so that the ventral view of the calyx is subpentangular. A semicircular excavation occupies nearly the entire distal edge of the radials, and the processes thus formed are rather short for the genus. The costals are not preserved in the type or any of the specimens at hand. The interradials or orals are large and are not visible in a side view; they comprise the greater part of the ventral disc. They extend to the top of the radial processes, and rest against their inner faces. Laterally they connect with each other, but leave a comparatively large round opening for the peristome in the center of the disc. The deflected lateral edges form the ambulacral groove extending from the arm bases to the central opening. The anal opening is situated at the juncture of the posterior interradial with the processes of the two posterior radials. None of the plates which covered the peristome, ambulacral grooves or anal opening is preserved.

The natural casts are similar in form to the exteriors, but slightly constricted at the arm bases and somewhat shorter in proportion to their diameter. The interradial processes are indicated by five rather stout protuberances between which the dorsal cup curves gradually into the convex ventral disc. A large circular protuberance in the center of the disc indicates the size and position of the peristome, and a small one rising out of the posterior interradial process indicates the anal opening.

Dimensions of the type are as follows:

Natural mold		Natural cast	
Height of calyx,	6.7 mm.	Height of calyx,	4.5 mm.
Height of basals,	3.3 "	Height of basals,	1.3 "
Height of radials,	2.4 "	Height of radials,	2.4 "
Height of processes,	1.0 "	Height of processes,	0.8 "
Diameter at arm bases,	5.0 "	Diameter at arm bases,	2.9 "
Diameter at top of basals,	4.1 "	Diameter at top of basals,	3.0 "

As to size, form and pattern of ornamentation, this species approaches *S. hammelli* S. A. M. * and from the original description and figures it would hardly be safe to separate them. Upon comparison, however, with the types of *S. hammelli*, which are in the paleontological collections of the University of Chicago, the ornamentation of the plates was found to be so much more prominent in the specimens here described as to warrant specific distinction. The striations in both species are so grouped as to form geometric figures. For instance, the longitudinal striae on the right posterior radial and the basal on which

* 17th Rept. Geol. Ind., p. 635, Pl. VI, Figs. 7-9.

it rests, are in the form of a rhomb, with its transverse axis equal to the width of the radial plate. In *S. skiffi* the rhomb consists of nine striae, but in *S. hammelli* there are more than three times that number. In *S. hammelli* moreover the curvature of the rhomb conforms to the general curvature of the calyx, but in *S. skiffi* it is decidedly convex transversely and moderately so longitudinally (Pl. LXXXIV, Fig. 16).

The type specimen (Mus. No. P 8479) consists of a natural cast and more than half the accompanying mold, both in an excellent state of preservation. Several other individuals of this species are in the collections.

The specific name is proposed in honor of Mr. Frederick J. V. Skiff, Director of the Museum.

Locality: Niagaran limestone of the spoil heaps of the Chicago Drainage Canal near Lemont, Illinois.

Family ZOPHOCRINIDÆ.

ZOPHOCRINUS S. A. Miller.

Two new species belonging to this genus were collected by the writer and are here described. This genus differs from all other crinoids in that the calyx contains but four radial plates; the quadrangular one is somewhat larger than the others and is probably made up of the right and left posterior radials fused, as the tetramerism affects the dorsal cup only; the dome and arms are pentameral.

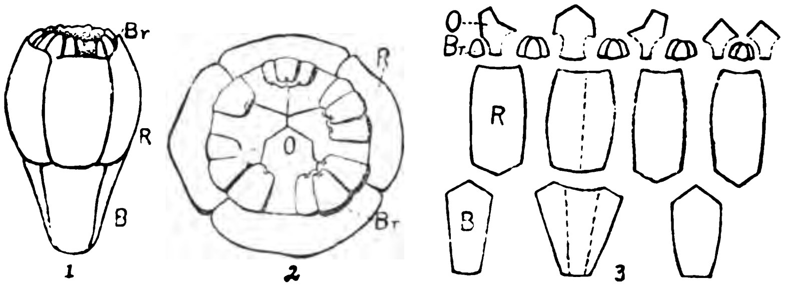


Fig. 5. Outline of the (1) Posterior and (2) Ventral Views of the Genotype and (3) Diagram of *Zophocrinus*. (After Bather.)

The plates are as follows: Basals three, two equal, one larger; radials four, three equal, one larger. The ventral disc is composed of five orals, the posterior oral is the largest and the two anterior orals are the smallest and are not in contact with the posterior one; anus unknown; five groups of arms are situated where the interoral sutures meet the radials: The distal edges of the radials are thickened on their inner side and are pierced by pores. The presence of these pores has been taken by some writers to indicate that the genus might belong to the cystoids, but for the present it is considered to be a crinoid.

ZOPHOCRINUS GLOBOSUS sp. nov. Plate LXXXV, Figures 15–19.

The calyx is small, in the form of a prolate spheroid, truncated at the top. The natural casts are subspherical, slightly flattened on six sides, approaching a rounded hexahedron. The plates are rather thick and smooth or possibly finely granulose, convex, slightly sloping towards the sutures, so that their shape and arrangement is easily studied.

Basal plates three, much thicker than the radials; two are quadrangular and about equal in size; the other is pentangular and larger; together they form a shallow rounded cup with a slight triangulation at the base and a circular depression for the reception of the column. Radials four, height and width about equal; three are pentangular, the other is quadrangular; their sides are subparallel, slightly contracted at either end. These plates have a decided thickening of the inner margin of their distal ends, which is shown by a deep groove on the natural casts. The ventral disc is not preserved on any of the specimens studied.

The species differs from the other species of the genus in its globose form, its relatively short radial plates and its rounded base, as compared with the pear-shaped body and attenuate obconical base of the other species. These characters are stated in more detail on a later page.

Locality: Niagaran limestone of the spoil heaps along the Drainage Canal, about a mile and a half east of Lemont, Illinois.

This species, while it cannot be said to be abundant in this Area, is by no means rare. Four specimens were collected by the writer in the fall of 1905 and a like number in the spring of 1906. The specimens consist of natural casts with more or less of the accompanying molds. The Museum number of the type specimen is P 8480.

ZOPHOCRINUS PYRIFORMIS sp. nov. Plate LXXXV, Figures 12–14.

The calyx is broadly pear-shaped, truncated at the top, expanding rapidly from the base to about the middle of the radials, from which point it contracts to the arm bases. The surface of the plates is finely granulose and moderately convex, sloping towards the sutures; this shallow depression indicates the position of the sutures.

The basal plates are three in number. Together they form an obconical cup comprising about one-third the height of the calyx. Two are quadrangular and equal in size, the other is pentangular and larger. The proximal end of each plate is provided with a decided median ridge, giving a triangular base to the cup in which is a circular depression for the reception of the stem. The radial plates are four, about equal in size, three pentangular and one quadrangular; the distal margins are thickened and beveled towards the interior. The beveled edge of each plate is pierced by pores, the exact number of which cannot be determined from this specimen.

This species is founded on a single silicified specimen (Mus. No. P 8415), having the dorsal cup complete and in a good state of preservation, but the dome is missing. In form it appears to occupy a position between that of *Z. howardi* and *Z. globosus*. The description of *Z. howardi** is as follows: "Body subovate or pear-shaped, greatest diameter at the upper third, pointed below, length more than twice the diameter; base subhexahedral." *Z. pyriformis* is distinguished from *Z. howardi* by being much shorter in proportion to its greatest diameter and by the form of the base; also the opening formed by the distal edges of the radial plates is much larger. From *Z. globosus*, which it resembles in general proportions, it differs in the form of the base and general outline of the calyx.

The comparative characters of the three species may be shown in tabular form as follows:

	Ratio of diameter to height	Form of base	Form of basal cup	Position of greatest diameter
Z. globosus	6:7	Hemispherical	Wider than high	Near middle
Z. pyriformis	3:4	Short triangular	Wider than high	Near middle
Z. howardi	1:2	Long hexagonal	Higher than wide	Upper third

Locality: The type specimen (Mus. No. P 8415) was collected by the writer in the clay pockets in the Niagaran limestone at Romeo, Illinois.

Examination of a large series of specimens of *Z. howardi* from St. Paul, Indiana, showed two individuals of *Z. pyriformis*.

---

* 17th Rept. Geol. Surv. Indiana, p. 643.

Order II. FISTULATA.

Family GASTEROCOMIDÆ.

ACHRADOCRINUS Schultze.

This genus was originally proposed by Schultze, to receive a species from the Devonian rocks of the Eifel, Germany. The species collected by the writer and here described is the first American species to be referred to the genus. The original description* of the genus is as follows: "The composition of the calyx is as follows: Basalia (infrabasals) five, equal, pentagonal; Parabasalia (basals) five, four equal, pentagonal, the fifth hexagonal; Radialia (radials) five, pentagonal, alternating with parabasalia (basals); Interradials (anal plate) one, resting on the horizontal, truncated edge of the hexagonal parabasal (basal) directly beneath the anal opening.

Ventral dome, arms and column unknown. The base is pierced by a single circular canal."

Genotype *Achradocrinus ventrosus*.

To the above description of the radial plates may be added the following, as the characters are generic: Radials five, shield-shaped; three regular and equal, the two posterior ones irregular, deeply excavated for the reception of the anal plate which they enclose on three sides by meeting above. A prominent articular facet occupies the outer side of the radials near their distal edges. The facets are provided with a ventral groove and are pierced by a small canal located at some distance from the groove.

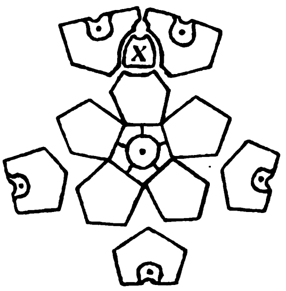


Fig. 6. Diagram of *Achradocrinus*. (After Schultze).

In referring *Achradocrinus* to the Gasterocomidae Schultze compares it with *Gasterocoma*, which it resembles in general arrangement of the plates and position of the anal interradius, but from which it differs in the form of the basal canal. In *Gasterocoma* the base is pierced by a quadrilobate canal and in *Achradocrinus* by a circular, central canal.

So far as is known to the writer, all genera heretofore referred to the Gasterocomidae have been of Devonian age.

* Monographie der Echinodermen des Eifler Kalkes, p. 101.

ACHRADOCRINUS PATULUS sp. nov. Plate LXXXV, Figures 1–4.

Dorsal cup depressed, obconical, truncated at the base, somewhat inflated on the posterior side so that the symmetry is bilateral. Surface of the plates granulose and moderately convex, forming shallow grooves in which the sutures are situated.

Infrabasals small, forming a disc which barely extends beyond the circumference of the column. The disc is provided with a central, circular canal, and the plates appear to be fused as the sutures are not visible. Basals five, four equal in size and shape, angular above, the posterior larger and truncated to support the anal plate. Radials five, three shield-shaped and equal, the two posterior radials deeply excavated for the reception of the anal plate which they enclose on three sides by meeting above. The distal edges of the radials are sharply inflected towards the center of the vault. A prominent, semicircular, articular facet, directed outward, occupies more than half the width of the radials. There is an axial canal situated at about the center of the facet and a wide, shallow ventral groove extends from the facet across the inflected edge of the radials. The anal plate is small, subquadrangular, its lateral edges arched and its distal edge excavated for the anal opening. It rests upon the posterior basal and between the posterior radials. The anal opening is situated in line with the arm facets directly above the anal plate and below the lateral extension of the adjoining radials. The opening is directed horizontally and is surrounded by a number of small plates. Arms unknown, but judging from the articular facets they appear to be widely divergent or possibly recumbent. Tegmen not preserved. Column circular with central canal.

The species here described is referred to the above genus, although differences from the genotype occur. These differences, however, are not considered to be of generic importance. Schultze's original figures are reproduced for comparison, Pl. LXXXV, Figs. 5–8.

With *A. ventrosus*, *A. patulus* compares as follows: In form and arrangement of the plates the two species are similar, likewise in the character of the stem and the articular facets with their ventral grooves and axial canals. In *A. ventrosus*, however, the five infrabasals are distinct and form a shallow cup visible in a side view of the calyx, but in *A. patulus* the infrabasals appear to be fused into a disc and inconspicuous. The type specimen of *A. patulus* is, however, silicified and it is quite probable that the basal sutures have been obliterated in the process of silicification. The anal opening in both species is situated between the distal edge of the anal plate and the lateral extensions of the posterior radials; but in the genotype the opening is directed vertically and is not visible in a side view of the calyx. In *A. patulus*, however, the opening is in line with the center of the arm facets, directed horizontally and visible only in a side view of the calyx.

Locality: The type specimen, Mus. No. P 8417, is a silicified dorsal cup in a good state of preservation. It was collected by the writer in the clay pockets of the Niagaran limestone at Romeo, in the fall of 1905.

Family CYATHOCRINIDÆ.

HOMOCRINUS Hall.

No members of this genus have been heretofore reported from this area, but two species, *H. ancilla* and *H. cylindricus*, were collected by the writer and are here described. The generic description is as follows: Calyx dicyclic, subcylindrical to turbinate. Infrabasals five; basals five; radials five, separated on the posterior side by an anal plate. The radianal plate is situated below the right posterior radial and between the right anterior radial and the anal plate; ventral sac long and large; arms bifurcating, without pinnules; stem round. Distinguished from *Dendrocrinus* by the proportionally larger infrabasals and from *Poteriocrinus* by the arrangement of the azygous plates.

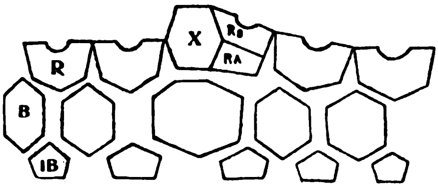


Fig. 7. Diagram of *Homocrinus*. (After Bather).

Homocrinus ancilla Hall, Plate LXXXV, Figures 9–11.

1879 *Dendrocrinus ancilla* Hall, Trans. Alb. Inst., Vol. X, p. 9.
1882 *Dendrocrinus ancilla* Hall, 11th Geol. Rept. Ind., p. 271.
1886 *Homocrinus ancilla* W. & Sp., Revis. Paleocrinoidea, Pt. III, p. 220.

Hall's description of this species is as follows: "Body narrowly turbinate, width and height above as ten to twelve or ten to thirteen; contracted between the arm bases; upper part of the column closely adhering to the body, the five minute basal plates (infrabasals) scarcely distinguishable from the segments of the column at its summit; subradial plates (basals) obscurely angular on the lower face, about three-fourths as wide as long, very gradually expanding in width from the base, and supporting on their upper adjacent sloping faces a large hexagonal interradial plate, and this supporting a single radial, from which the arms take their origin. Arms unknown."

A detailed description of specimens from the Chicago Area is as follows: Calyx narrowly turbinate or trumpet-shaped; arm bases prominent with constrictions between; surface of the plates smooth; sutures situated in small, but well-defined furrows; base dicyclic.

Infrabasal plates five, equal in size, pentagonal, higher than wide. Basals five; height and width about as 4:3; four are hexagonal and the posterior one is heptagonal, being truncated to support the anal plate on its distal edge. The infrabasals and basal plates together form a deep cup, its base apparently about the size of the upper joints of the column. It expands very moderately until the middle of the basals is reached, from which point the expansion is quite rapid to the arm bases. Radial plates five, very much thickened in the middle of their distal edges to form the prominent facets for the attachment of the arms; these facets occupy about half the width of the plate. The right posterior radial is smaller than the others, on account of the radianal plate being interposed between the anal plate and the right anterior radial; it rests on two of the basals and supports the right posterior radial; it is quadrangular in form. The anal plate is situated in line with the radials and rests on the truncated distal side of the posterior basal; it joins the left posterior radial on one side and the right posterior radial and the radianal on the other.

The natural casts conform in a general way with the outline of the outside of the plates, with the exception of the base, which terminates in a point, and the region of the arm bases, which is quite constricted on account of the thickening of the distal portions of the radial plates. The greatest diameter of the natural casts is at the middle of the radials, but that of the outside of the plates is at the arm bases.

This species was originally described from the Niagaran shales at Waldron, Indiana, and while the Chicago specimens do not agree in all respects with the original description, there seems to be little doubt that they should be referred to this species. In regard to the size of the infrabasals Hall's description and figure do not agree. Moreover, many characters, some of which, such as the size and position of the anal plates, are of generic importance, are incompletely described or are omitted altogether by Hall.

Locality: The specimens from the vicinity of Chicago consist of natural casts with the accompanying molds. The species was collected by the author in the spoil heaps along the Chicago Drainage Canal near Lemont, Illinois. The specimen used for the illustration is said to have been collected at Joliet, Illinois, and is in the collection of the Joliet High School.

HOMOCRINUS CYLINDRICUS Hall, Plate LXXXIV, Figures 14, 15.

1852 *H. cylindricus* Hall, Pal. N. Y., Vol. II, p. 186, Pl. XLI, Figs. 2 and 3.
1859 *Poteriocrinus cylindricus* Hall, Correct List of N. Y. Fossils.
1879 *H. cylindricus* W. &. Sp., Revision Paleocrinoidea, Pt. I, p. 78. Pt. III, p. 220.

Calyx subcylindrical, gradually enlarging to the top of the infrabasals and slightly constricted at the arm bases. Surface of the plates smooth and conforming to the general curve of the calyx, except the radials which are longitudinally convex at the arm facets, giving a lobed appearance to the upper part of the calyx; lobes thick. Infrabasals five, equal, pentagonal, higher than wide, forming a cup whose height and width are about equal. Basals four, higher than wide, the largest plates of the calyx. The posterior basal is heptagonal, being truncated distally for the support of the anal plate. It is somewhat larger than the other four which are hexagonal and equal in size. Radials five, wider than high, somewhat smaller than the infrabasals. The articulating facets for the arms occupy nearly the entire distal edge of the plate. The right posterior radial is smaller than the others, on account of the proximal end being displaced by the radianal plate. The radial symmetry is disturbed by the presence of an anal plate situated between the two posterior radials and resting on the posterior basal, and a radianal plate is situated at the right of the anal, resting on the posterior and right lateral basal plates and carrying on its distal side the right posterior radial.

The species occurs in this locality in the form of natural casts and molds. Owing to the comparative thickness of the plates the casts are quite different in shape from the molds. The infrabasal cup is in the form of a rapidly expanding pyramid. Owing to the convexity of the inner surface of the basal plates there is a noticeable constriction a little above the middle of the cast and another at the arm bases. These features are well shown in Pl. LXXXIV, Fig. 15. Hall's original description* of this species is brief, and, judging from his figures, his specimens were not very well preserved. There seems to be little doubt, however, that this specimen should be referred to this species. The species was described from the Niagaran shale at Lockport, New York, and, so far as is known to the writer, has never been reported from any other locality.

---

* Pal. N. Y., Vol. II, p. 186.

Locality: Collected by the writer in the spoil heaps along the Chicago Drainage Canal about 1⅓ miles east of Lemont, Illinois. (Mus. No. P 8887.)

Family CROTALOCRINIDÆ.

CROTALOCRINUS Austin.

CROTALOCRINUS CORA Hall, Plate LXXXVI, Figs. 3 and 4.

1868 *Cyathocrinus cora* Hall, 20th Rept. N. Y. St. Mus., p. 324, Pl. XI, Figs. 13, 14.

1870 *Cyathocrinus cora* Hall, 20th Rept. N. Y. St. Mus. (Rev. Ed.), p. 366, Pl. XI, Figs. 13, 14.

1879 *Cyathocrinus cora* W. & Sp., Rev. Paleocrin., Pt. I, p. 85.

1881 *Cyathocrinus cora* S. A. M., Jour. Cin. Soc. Nat. Hist., Vol. IV, p. 171.

1900 *Cyathocrinus cora* Weller, Bull. 4, Nat. Hist. Surv. Chicago Acad. Sci., p. 62, Pl. XIV, Figs. 6–10.

1900 *Crotalocrinus americanus* Weller, ibid. p. 143, Pl. XIV, Fig. 1.

1902 *Crotalocrinus cora* Weller, Jour. Geol., Vol. X, p. 532, Pl. III.

This species is abundant at various localities in the vicinity of Chicago and at Racine, Wisconsin, in the form of natural casts, but it is rarely found with the brachial plates preserved. The specimen here figured (Mus. No. P 8809) shows the anterior and right anterior rays, complete to the fourth bifurcation of the brachials, and part of the left anterior and right posterior rays. This is probably the most complete specimen of this species yet discovered. The specimen consists of a natural cast with more than half the accompanying mold. Fig. 3 is drawn from a "composition" impression taken from the natural mold. Collected by the writer in the upper layers of the Hawthorne Quarry, Chicago, May, 1906.

Order III. CAMERATA.

Family PLATYCRINIDÆ.

PLATYCRINUS Miller.

PLATYCRINUS AUGUSTA sp. nov. Plate LXXXVI, Figures 5–7.

Dorsal cup subhemispherical, sharply constricted above, with the base produced into a circular facet for the attachment of the column. Pentangular in transverse section at the arm bases, circular below. Plates thin, without ornamentation, conforming to the curvature of the calyx; sutures not in furrows, inconspicuous.

The natural cast is similar in form and proportions to the outside of the calyx without the radial and basal facets. The transverse ridge near the arm bases is more prominent and the inner surface of the plates is slightly beveled towards the edges, so that the position of the sutures is indicated on the casts by indistinct ridges.

Basals three, two pentangular and equal, the other smaller, quadrangular. Together they form a cup wider than high and with a small circular base. Radials five, about equal in size, three pentangular, two quadrangular. The radials are inflected on a line with the lower part of the articular facet forming an obtuse angular transverse ridge. The articular facets are small, occupying about one-third the width of the plates. They are circular in outline with a deep ventral groove. One axillary costal is attached to each articular facet. Column, as indicated by the basal facet, round with a central circular canal. Arms and ventral disc not preserved.

The type specimen (Mus. No. P 8895) consists of a natural cast of the dorsal cup and the associated natural mold nearly complete. Figures 5 and 6, Plate LXXXVI, are drawn from a rubber impression of the natural mold. This species is so different in its general form from any other species of this genus that comparison seems superfluous. The specific name is proposed in honor of the wife of the writer.

Locality: Collected by the writer in the Niagaran limestone of the spoil heaps along the Chicago Drainage Canal near Lemont, Illinois.

Family BATOCRINIDÆ.

HABROCRINUS Angelin.

Calyx obconical to urn-shaped; composed of thick, more or less ornamented plates. Arms, two to each ray; uniserial, long, heavy and simple throughout. Base monocyclic.

Basals three, equal. Radials five, each followed by two costals. Distichals two to six to each ray leading up to the arms. First anal plate large, situated between the two posterior lateral radials. It is followed by three plates in the second row and five in the third. The anal interradius is much wider than the other interbrachial areas.

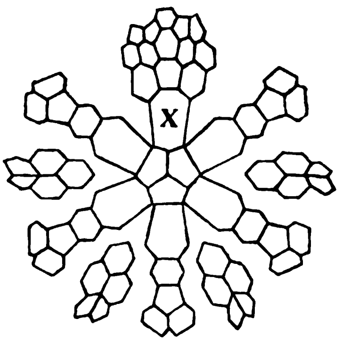


Fig. 8. Diagram of *Habrocrinus*.

The genus *Habrocrinus* together with *Pionocrinus* was created in

1878 by Angelin* to receive a number of species from the Silurian rocks of Gotland, Sweden. It has been recognized in the Wenlock limestone in England, and Wachsmuth and Springer described two species from Indiana which they referred to the subgenus *Acacocrinus*. The differences between *Habrocrinus* and *Pionocrinus* are as follows: In *Habrocrinus* the interbrachial areas consist of one plate resting on the superior lateral edges of the radials, followed by two plates in each of the succeeding rows; in *Pionocrinus* the first interbrachial plate is large, occupying the space between the two rays from the superior lateral edges of the radials to the inferior edges of the first distichals. This plate is followed by a single narrow plate. The first costals in *Habrocrinus* are hexangular, while those of *Pionocrinus* are quadrangular. These differences are not considered to be of generic importance, so that Bather and Wachsmuth & Springer place the species originally referred to *Pionocrinus* in the genus *Habrocrinus*.

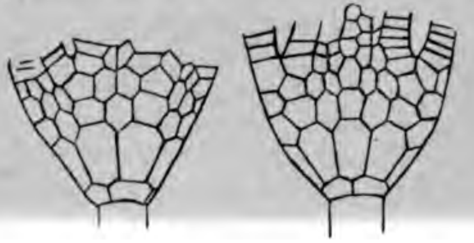


Fig. 9. Outline of *Habrocrinus ornatus* Ang. Lateral and Posterior Views. (After Angelin).

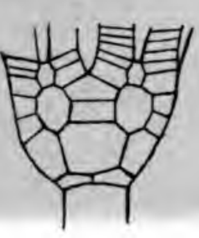


Fig. 10. Outline of *Pionocrinus farctus* Ang. Lateral View. (After Angelin).

Habrocrinus differs from *Periechocrinus* in character and ornamentation of the plates of the dorsal cup; in the former the plates are thick, more or less sculptured, sutures situated in deep furrows; in the latter the plates are thin, edges not beveled and position of sutures not well defined. In *Habrocrinus* the arms are strong and simple; in *Periechocrinus* they are slender and branching. In the former the palmers are not present in the dorsal cup; in the latter they are present. In the former the number of arms is two to each ray, in the latter it is four or more to each ray.

Of the fourteen American species referred to *Periechocrinus*, four species, *P. benedicti* S. A. M., *P. chicagoensis* Weller, *P. howardi* S. A. M. and *P. ornatus* Hall, possess characters which appear to necessitate their removal from that genus to *Habrocrinus*. The characters referred to are as follows: The absence of the palmers in the dorsal cup, reducing the number of arm bases from four to two in each ray, and the thick, more or less sculptured plates with edges beveled forming furrows in which the sutures are situated. As none of these species has been found with the arms preserved, it is not possible to state whether they are simple or branched, but the number of the arm bases and the thickness and ornamentation of the plates indicate their affinity with *Habrocrinus*. In the new species described herewith both the typical form of *Habrocrinus* and the form referred to *Pionocrinus* are found.

---

* Iconographia crinoideorum, p. 3.

HABROCRINUS BENEDICTI S. A. Miller, Plate LXXXVII, Figs. 6-7.

1892 *Saccocrinus benedicti* S. A. M., Adv. Sheets, 18th Rept. Geol. Surv. Ind., p. 28, Pl. V, Figs. 1–2.

1894 *Saccocrinus benedicti* S. A. M., 18th Rept. Geol. Surv. Ind., p. 283, Pl. V, Figs. 1–2.

1902 *Periechocrinus chicagoensis* Weller, Bull. 4, Nat. Hist. Surv., Chicago Acad. Sci., p. 131, Pl. XIII, Figs. 7–8.

The specimens described by S. A. Miller as *Saccocrinus benedicti* had the plates preserved, so that their form and ornamentations were well shown. The specimens were from St Paul, Indiana. *Periechocrinus chicagoensis* was described by Weller from natural casts from Chicago, no specimens showing the ornamentation of the plates having at the time been reported.

In the summer of 1906 the writer was fortunate enough to find a natural cast of *P. chicagoensis* accompanied by a large part of the natural mold. Upon taking an impression of this mold a great similarity with *P. benedicti* was at once apparent, and upon further study of the two forms there appeared little reason to doubt that they were specifically identical. As Miller's species has about ten years priority, *P. chicagoensis* Weller will thus become a synonym. Wachsmuth & Springer consider *H. benedicti* to be a synonym of *H. ornatus*. This view is not held by many other authors and a comparison of the type of *H. benedicti* with the drawings of *H. ornatus* would seem to leave little room to doubt that they are distinct.

Locality: Niagaran limestone of the spoil heaps along the Chicago Drainage Canal near Lemont, Illinois. The specimen here figured has the Museum number P 8893.

The bibliography of the two other species transferred to Habrocrinus is here given, although they have not been reported from this Area.

HABROCRINUS HOWARDI S. A. Miller.

1892 *Saccocrinus howardi* S. A. M., Adv. Sheets, 18th Rept. Geol. Surv. Ind., p. 29, Pl. V, Figs. 3-5.

1894 *Saccocrinus howardi* S. A. M., 18th Rept. Geol. Surv. Ind., p. 284, Pl. V, Figs. 3-5.

1897 *Periechocrinus howardi* W. & Sp., N. Am. Crin. Cam., Vol. II, p. 529.

Niagara Group, St. Paul, Indiana.

HABROCRINUS ORNATUS Hall.

1875 *Saccocrinus ornatus* Hall, Pal. Ohio, Vol. II, p. 126, Pl. VI, Figs. 7-9.

1881 *Periechocrinus ornatus* Wachsmuth & Springer, Rev. Palaeocr., Pt. II, p. 132.

1897 *Periechocrinus ornatus* Wachsmuth & Springer, N. Am. Crin. Cam., Vol. II, p. 527, Pl. L, Figs. 3a-b, and Pl. LI, Fig. 7.

Niagara group, Yellow Springs, Ohio.

HABROCRINUS FARRINGTONI sp. nov. Plate LXXXVII, Figs. 1-5.

The calyx is urn-shaped, with an expanded hexagonal base. The dome is not preserved. The plates of the dorsal cup are thick, depressed in the center, with low nodes near the angles. The sutures are situated in deep furrows formed by the beveled edges of the plates. No radial ridges are found. The natural casts have a pronounced tubercle near the center of the radial and first anal plates, indicating a depression on the inner side of the plates, but no corresponding elevation, on the exterior of the plates, is shown in the natural mold. The natural casts are pyriform, pointed below and truncated above, somewhat constricted between the prominent arm bases. Arms, judging from the arm bases, two to each ray.

Basals three, equal, forming a shallow hexagonal cup. Radials five, height and width about equal; the two anterior laterals heptagonal, the others hexagonal. First costals hexagonal, about half the size of the radials; second costals smaller than the first, pentagonal, axillary, bearing the distichals upon their superior edges. First distichals about twice as high as wide. Higher plates of the rays not known. First interbrachials hexagonal; equal in size or slightly larger than the first costals; they are followed by two somewhat smaller plates, and these by two still smaller which join with the plates of the dome. No interdistichal plates visible. The anal interradius has nearly the combined width of one of the rays and two interbrachial areas. The first anal plate is situated between the two posterior radials, resting on the basals. It is heptagonal in form and from its superior edge extends a row of three or more plates, gradually diminishing in size; these anal plates are similar in size to the corresponding radial, costal and distichal plates; on either side of the anal plates is a series of plates similar to, but slightly smaller than, those of the interbrachial areas, with the exception that there are three in the third row instead of two.

This species somewhat resembles *H. benedicti* S. A. M. in general appearance, but it is distinguished from that species by having a more shallow and expanded basal cup. The diameter of the calyx is greater in proportion to its height in *H. farringtoni* than in *H. benedicti*, and both the constriction below the arm bases and the second and third distichals are wanting in *H. farringtoni*. In the form of the calyx and the ornamentation of the plates *H. farringtoni* resembles *H. lemontensis*, but they are distinguished by the shape of their first costals and by the number and shape of the plates in the interbrachial areas.

The type specimen of *H. farringtoni*, on which this description is based, consists of a natural cast of the dorsal cup accompanied by a portion of the natural mold. The sutures are well defined on both cast and mold. The mold comprises two rays, one interbrachial area and more than half the anal interradius. An impression taken from this mold gives the external form of the calyx and the surface markings of the plates. As the basal plates are missing from this mold, the impression of a mold in the collection of the University of Chicago is also figured, Plate LXXXVII, Figs. 1 and 2. The type is somewhat crushed, thus giving a wider appearance in proportion to its height than is natural.

The specific name is proposed in honor of Dr. O. C. Farrington, Curator of the Department of Geology of the Museum.

Locality: This species is represented in the Museum collections by the type specimen P 8474, and a natural cast, P 8949. These were collected by the writer in the Niagaran limestone of the spoil heaps along the Chicago Drainage Canal about a mile east of Lemont, Illinois, one in the fall of 1905 and one in the spring of 1906. The specimen in the collection of the University of Chicago is from the same locality.

HABROCRINUS LEMONTENSIS sp. nov. Plate LXXXVII, Figs. 8–10.

The calyx is urn-shaped with an expanded hexagonal base; moderately constricted between the prominent arm bases, giving a pentagonal section to the dorsal cup. The dome is not preserved. The plates of the dorsal cup are thick and depressed with nodes near the angles of the plates. The sutures are situated in deep furrows formed by the beveled edges of the plates. No radial ridges are observed. The natural cast is turbinate, pointed below and truncated above, with prominent arm bases. Arms, judging from the arm bases, two to each ray.

Basals three, equal in size, forming a shallow cup with an hexagonal outline. Radials five, height and width about equal, the two anterior laterals heptagonal, the others hexagonal, in contact except at the posterior side where they are separated by the first anal plate. First costals quadrangular, height and width about equal, much smaller than the radials. Second costals about the size of the first, wider than high, pentangular, axillary, supporting the distichals upon their sloping edges. Distichals comparatively large, two or more to each ray. The first interbrachial plate is intermediate in size between the radials and the first costals; it is nine-sided and occupies the space from the sloping superior edges of the radials to the inferior edges of the distichals; it supports a narrow plate upon its upper edge. No interdistichals are observed. The anal interradius is considerably wider than the interbrachial areas. The first anal plate is heptagonal, resting on the basals between the posterior lateral radials. It is followed by three plates in the second row and by five in the two succeeding rows.

In the arrangement and relative size of the plates this species closely resembles *H.* (*Pionocrinus*) *farctus* Angelin * (See Fig. 10), but that is a very small species and the plates are moderately convex and without sculpturing. The distinguishing characters between this species and *H. farringtoni* are discussed under that species.

The type specimen (Mus. No. P 9628) consists of a somewhat weathered natural cast with a portion of the accompanying natural mold. The mold comprises the basal cup in good condition, three radials and the first anal plate practically complete and the lower half of the other two radials; in two of the rays the costals and one of the distichals are preserved with the enclosed interbrachial area. The impression from this mold gives the general form of the exterior of the dorsal cup and the ornamentation of the plates. The form of more than half of the plates can be traced on the natural cast, so that the characters of the species can be ascertained. The pits on the basal and radial plates, shown in Pl. LXXXVII, Figs. 8 and 9, are caused by protuberances in the natural mold. These protuberances appear to be carbonate of lime deposited after the original crinoid had been dissolved out, and probably have no connection with the ornamentation of the plates.

---

* Iconographia Crinoideorum, p. 5, Pl. XVI, Fig. 23.

Locality: The species is represented by a single individual collected by the writer in the fall of 1905, in the Niagaran limestone in the spoil heaps along the Chicago Drainage Canal, about one mile east of Lemont, Illinois.

Family THYSANOCRINIDÆ.

THYSANOCRINUS Hall.

Weller's description* of this genus is as follows:—

"Calyx subglobose, urn or bell-shaped, the rays marked by more or less conspicuous ridges; the surface of the plates smooth, or variously ornamented. Infrabasals five small, barely extending beyond the column, or entirely hidden by it. Basals five, four of them equal and angular above; the fifth truncated and supporting a large anal plate. Radials considerably larger than the costals, their proximal sides distinctly angular, the lateral faces comparatively short. Costals two. Distichals two or three in each series. In some cases palmers are also present, the axillary distichal giving rise on the interradial side to an armlet for the most part included in the calyx and on the other side of the main arm. Four of the first interbrachials large, angular below, resting upon the sloping upper corners of the two radials and against the costals; two plates in the second row, often followed by smaller ones above which connect with the plates of the disc. The anal side considerably wider, the first plate large, hexagonal, resting upon the truncated posterior basal, three plates in the second row and smaller ones above. In some species an uninterrupted row of anal plates extends to the anal opening. Interdistichals generally represented and rather large. Column round or obtusely pentangular."

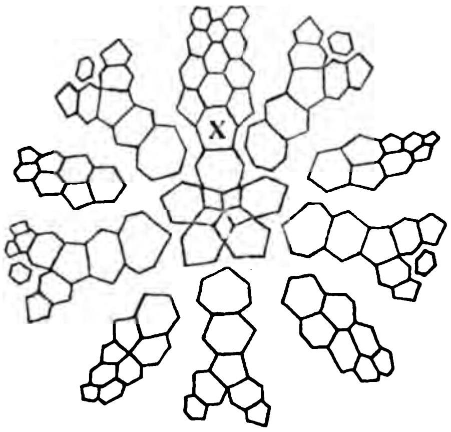


Fig. 11. Diagram of *Thysanocrinus*.

THYSANOCRINUS CAMPANULATUS sp. nov. Plate LXXXV, Figs. 20–23.

The calyx is bell-shaped, expanding very rapidly above the top of the radial plates. The diameter of the dorsal cup at the arm bases is about one-half greater than the height of the cup. The dorsal cup is ornamented with series of prominent rounded ridges. The ridges begin near the middle of the lower margins of the basal plates at the juncture with the column and extend to the center of the plate. At this point they bifurcate and pass to the center of the radials where they join the ridges from the basals on either side. From the center of the radials the ridges follow the median line of the radials and costals to the middle of the axillary costal where they again bifurcate and follow the distichals up to the arm bases. Another, less conspicuous ridge connects the centers of the posterior lateral radials crossing the first anal plate. Surface of all plates, not ornamented with the ridges, smooth and moderately convex. Sutures not situated in grooves. In the natural casts the dorsal cup is broad and flat at the base and curves abruptly upward at about the middle of the basal plates; it expands moderately up to the middle of the radials, where a slight constriction occurs, and above this constriction the expansion is very rapid until at the arm bases the plates are nearly at right angles to the axis of the calyx. Ventral disc not preserved.

---

* Bull. IV, Pt. I, Nat. Hist. Surv., Chicago Acad. Sci., p. 70.

Infrabasals five, small, scarcely extending beyond the columnar facet. Basals five, large, forming with the infrabasals a shallow cup; the posterior basal is heptagonal and larger than the others which are hexagonal. Radials five, larger than the basals; the two posterior laterals are hexagonal and the rest are heptagonal. First costals hexagonal, less than half the size of the radials. Second costals axillary, pentagonal or hexagonal. In some cases the interdistichal appears to join the axillary costal. Distichals two or more in each series. First interbrachials are hexagonal, intermediate in size between the radials and first costals; they are followed by three or more rows of two plates each, diminishing in size upward. Interdistichals present, but in the specimens at hand only the first plate is preserved; this appears to be hexagonal or heptagonal. The anal interradius is wider than the interbrachial areas. The first anal plate is hexagonal, smaller than the radials; it rests on the distal edge of the posterior basal and separates the posterior lateral radials; it supports on its distal edge a row of plates, diminishing in size, which lead up to the vault; the space between this row of plates and the posterior lateral rays is filled with smaller plates.

In its general form and proportions this species is so unlike all other species of this genus that it will be easily recognized.

The type specimen, P 8891, was collected by the writer in the spring of 1906. It consists of a nearly perfect natural cast of the dorsal cup accompanied by a natural mold of which a part of the base is missing.

Locality: Niagaran limestone of the spoil heaps along the Chicago Drainage Canal near Lemont, Illinois.

Family CALYPTOCRINIDÆ.

EUCALYPTOCRINUS Goldfuss.

EUCALYPTOCRINUS OBCONICUS Hall, Plate LXXXVI, Figures 1–2.

1867 *E. obconicus* Hall, 20th Rept. N. Y. St. Mus., p. 323, Pl. XI, Fig. 1.
1870 *E. obconicus* Hall, 20th Rept. N. Y. St. Mus., Rev. Ed., p. 365, Pl. XI, Fig. 1.
1885 *E. obconicus* Wachsmuth & Sp., Rev. Palæocr. Pt. III, p. 133.
1897 *E. obconicus* Wachsmuth & Sp., N. Am. Crin. Cam., Vol. I., p. 353, Pl. LXXXIII, Fig. 13.
1900 *E. obconicus* Weller, Bull. 4, Nat. Hist. Surv., Chicago Acad. Sci., p. 109, Pl. VII, Fig. 8.

Dorsal cup obconical, truncated at the base by the attachment for the column; height nearly twice its diameter at the arm bases; gradually and regularly expanding from the size of the column at its base to the arm bases where it attains its greatest diameter. The plates are thicker in the central portion than at the edges, so that both their inner and outer surfaces are convex. The outer surface of the plates is smooth and slopes gently towards the sutures. The natural cast is similar in outline to the exterior of the dorsal cup, but it is pointed at the base. The position of the sutures is indicated by low angular ridges which are formed by the convexity of the inner surface of the plates.

Basals four, three pentagonal, one hexagonal, long and narrow. Together they form a cup, height and width about equal. Radials five, the largest plates in the calyx; four heptagonal, the other hexagonal, about equal in size and nearly twice as high as wide. First costals quadrangular, higher than wide, proximal and lateral edges arched, distal edges much narrower than the proximal ones. Second or axial costals are in the form of a regular pentagon, somewhat smaller than the first costals. Distichals four to each ray. The first pair hexagonal, in contact with each other and about the size of the second costals upon which they rest. The second pair is very small. First interbrachials ten-sided, about twice as high as wide and next to the radials in size. These are followed by two long narrow plates, with their longest edges in contact. Interdistichals small, angular below and resting upon the short, sloping edges of the first distichals and between the second distichals.

Arms and ventral disc not preserved.

The following dimensions are given for comparison. Those of the type are taken from the cut, those of this specimen from the cast.

	This specimen	Type specimen
Length of dorsal cup,	37.5 mm.	19.0
Diameter at arm bases,	18.2	13.5
Diameter at top of radials,	11.1	8.0
Height of radials,	12.5	5.2
Height of basals,	7.7	2.5

Owing to the fact that this specimen is somewhat distorted, the dimensions of the diameters as given are estimated. The actual measurements are as follows:

The longer and shorter diameters at arm bases are 22.15 and 14.3 respectively:

The longer and shorter diameters at top of radials are 12.9 and 9.3 respectively.

The specimen here described (Mus. No. P 8879) consists of a practically complete natural cast accompanied by a portion of the mold. The mold comprises one complete ray, a portion of two others and part of three interbrachial areas. So far as known to the writer, this is the first specimen of this species in which the external characters of the plates have been described or figured. This specimen differs from the type as figured by Hall in several particulars, and if other specimens should be found showing these characters to be constant, it may be advisable to consider this a new species. This specimen is about twice the length of the type and somewhat more slender. The basals, radials, first costals and first interbrachials are much higher in proportion to their width. In the type the sutures between the first costals and first interbrachials are straight, but in this specimen they are arched, with the convex side towards the interbrachial.

This species is distinguished from all other species of the genus by the absence of a basal cavity.

Locality: Niagaran limestone of the spoil heaps along the Chicago Drainage Canal near Lemont, Illinois.

Previous to the present publication there have been described from the Chicago Area a total of 62 species of crinoids divided among 26 genera. A complete list of these was given by Weller in 1900.* Two years later Weller obtained a specimen which showed that *Cyathocrinus cora* Hall and *Crotalocrinus americanus* Weller were one and should be known as *Crotalocrinus cora* Hall, † thus making the number of species 61. The species obtained by the present writer increase the total number of species of crinoids known from the Chicago Area to 75 and that of the genera to 30. A full list of these follows. In addition it may be noted that several specimens which were associated with those here described and which are evidently new species proved too fragmentary for description. Should better specimens of these be obtained, three or more new species and at least one new genus may be added to the list.

* Bull. 4, Nat. Hist. Surv., Chicago Acad. Sci., Pt. I.

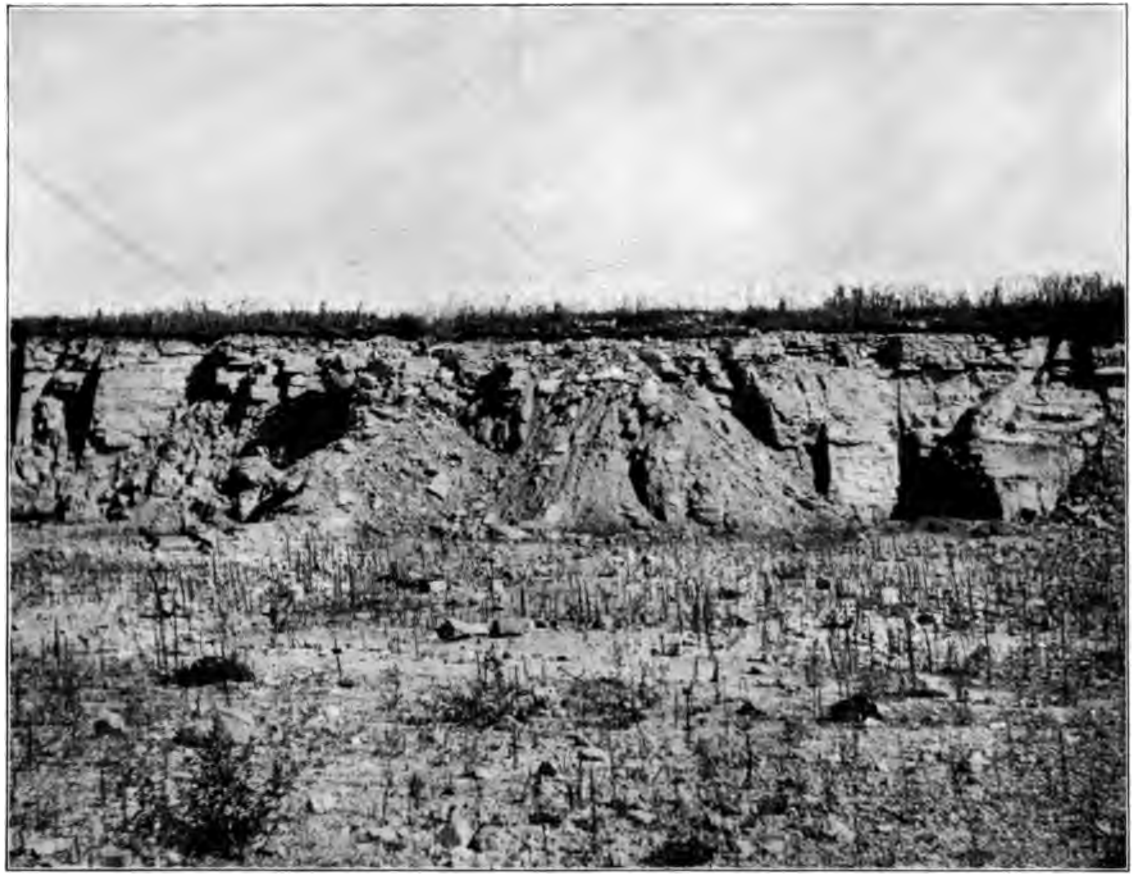
† Jour. Geol., Vol. X, pp. 532-4.

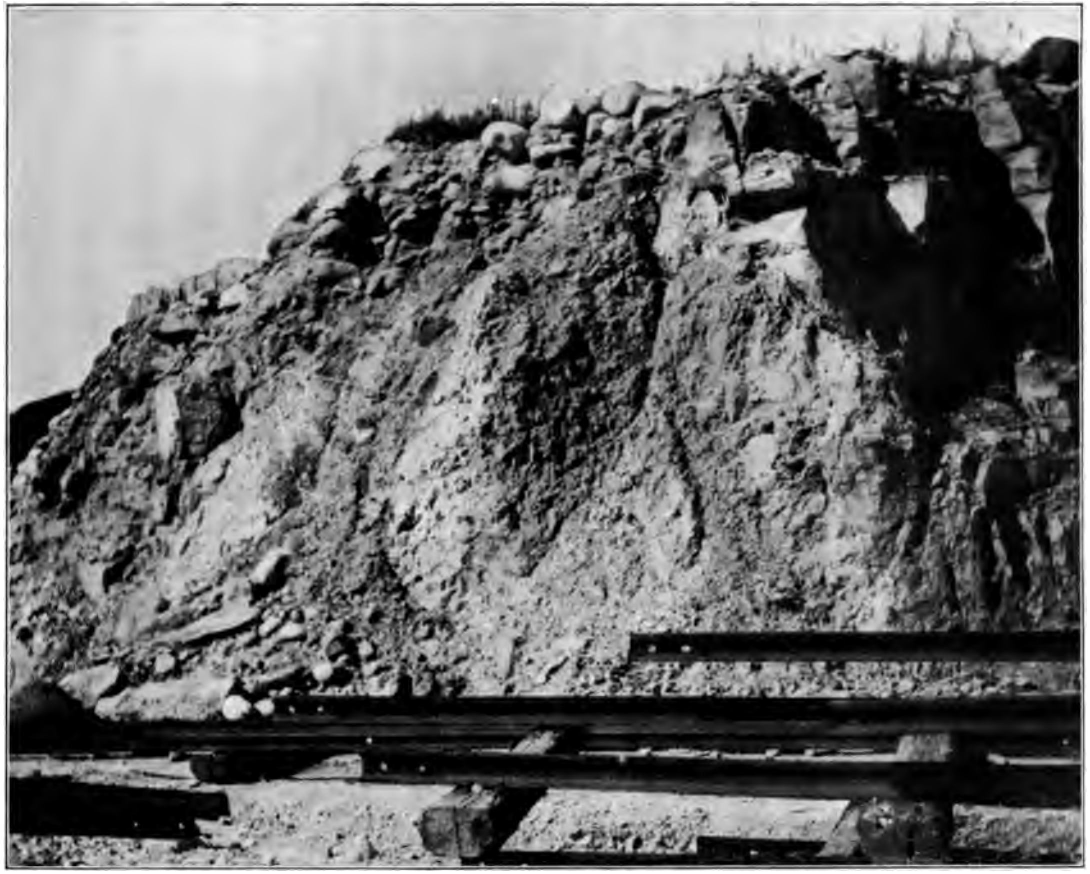
ACKNOWLEDGMENTS.

The writer is indebted to the publications of Wachsmuth & Springer, F. A. Bather and Stuart Weller for most of the generic descriptions used in this paper, but, as they have been rearranged and adapted more or less, they have not been treated as quotations. In any cases where descriptions have been copied due credit has been given.

The writer is also under obligations to Professor Weller of the University of Chicago for the use of publications, types and other specimens from the collections of Walker Museum, which have materially aided in the preparation of this paper.

The drawings illustrating the paper were made by Mr. Leon L. Pray of the Museum.





EXPLANATION OF PLATE LXXXIV.

Pisocrinus gemmiformis S. A. Miller, page 278.

Figs. 1, 2. Posterior and basal views of the type specimen, (after Miller). ×2.

Figs. 3, 4. Lateral and basal views of a natural mold with natural cast in position. ×2.

Pisocrinus quinquelobus Bather, page 280.

Fig. 5. Basal view of a specimen from Tennessee (after S. A. Miller). ×2.

Figs. 6, 7. Posterior and ventral views of a specimen from Romeo, Illinois. ×2.

Pisocrinus benedicti, S. A. Miller, page 279.

Fig. 8. Lateral view of a rubber impression of a natural mold. ×2.

Fig. 9. Basal view of a rubber impression of another natural mold. ×2.

Figs. 10, 11. Basal and lateral views of a natural mold with the natural cast in position. ×2.

Stephanocrinus obconicus sp. nov., page 281.

Figs. 12, 13. Posterior and basal views of the type specimen. ×2.

Homocrinus cylindricus Hall, page 291.

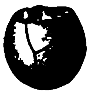
Fig. 14. Lateral view of a rubber impression of the natural mold. ×2.

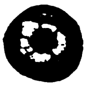
Fig. 15. Posterior view of the natural cast of the same individual. ×2.

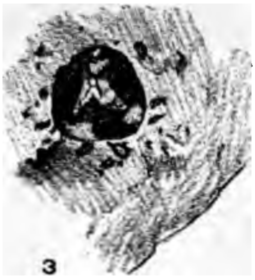
Stephanocrinus skiffi sp. nov. page 282.

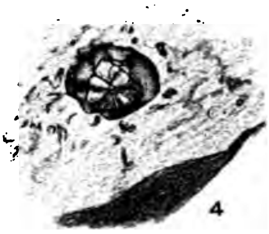
Figs. 16, 17. Lateral and ventral views of a rubber impression of the natural mold of the type specimen. ×2.

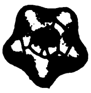
Figs. 18-20. Lateral, anterior and ventral views of the natural cast of the same individual. ×2.

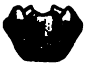

1

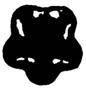

2

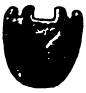

3

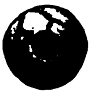

4

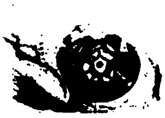

5

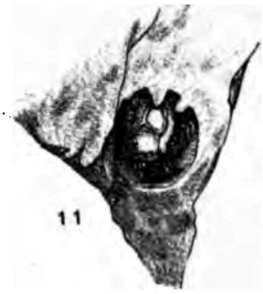

6

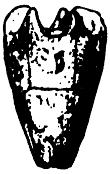

7

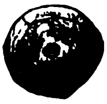

8

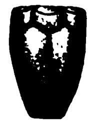

9

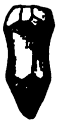

10

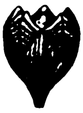

11

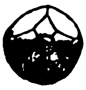

12

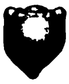

13

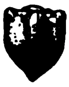

14

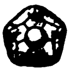

15


16


17


18


19


20

EXPLANATION OF PLATE LXXXV.

ACHRADOCRINUS PATULUS sp. nov., page 288.

Figs. 1-4. Posterior, lateral, basal and ventral views of the type specimen. ×2.

ACHRADOCRINUS VENTROSUS Schultze, page 288.

Figs. 5-8. Posterior, lateral, basal and ventral views of the genotype from the Devonian of Eifel, Germany (after Schultze), reduced one-half for comparison with above.

HOMOCRINUS ANCILLA Hall, page 289.

Fig. 9. Lateral view of a plaster impression of a natural mold. ×1.

Figs. 10, 11. Posterior and anterior views of a natural cast of the same individual. ×1.

ZOPHOCRINUS PYRIFORMIS sp. nov., page 285.

Figs. 12-14. Posterior, lateral and basal views of the type specimen. ×2.

ZOPHOCRINUS GLOBOSUS sp. nov., page 285.

Fig. 15. Lateral view of a rubber impression of the natural mold of the type specimen. ×2.

Fig. 16. Lateral view of the natural cast of the same individual. ×2.

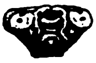
Fig. 17. Outline showing size and position of the natural cast and mold. ×2.

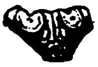
Figs. 18, 19. Basal and lateral views of another natural cast. ×2.

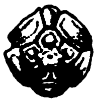
THYSANOCRINUS CAMPANULATUS sp. nov., page 290.

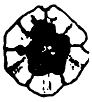
Figs. 20, 21. Lateral and posterior views of a composition impression of the natural mold of the type specimen. Somewhat restored at the base. ×1.

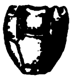
Figs. 22, 23. Posterior and basal views of the natural cast, same individual. ×1.

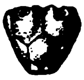

1

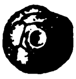

2

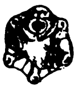

3

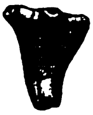

4

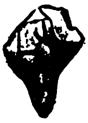

5

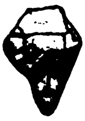

6

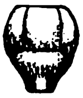

7

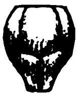

8

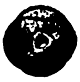

9

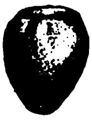

10

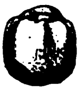

11

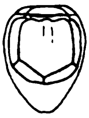

12

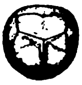

13

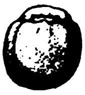

14

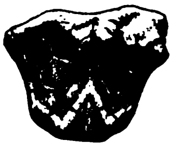

15

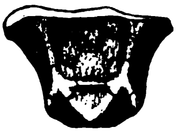

16

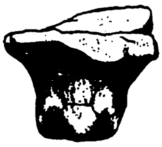

17

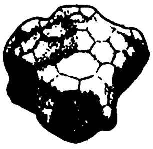

18


19


20


21


22


23

EXPLANATION OF PLATE LXXXVI.

EUCALYPTOCRINUS OBCONICUS Hall, page 301.

Fig. 1. Natural mold with the natural cast in position. × 1.

Fig. 2. Lateral view of a plaster impression of the natural mold. × 1.

CROTALOCRINUS CORA Hall, page 292.

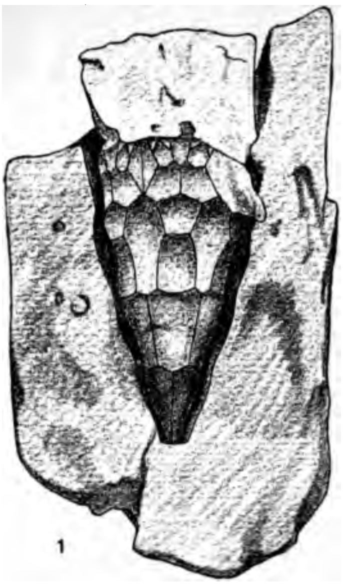
Fig. 3. Anterior view of a composition impression of the natural mold. × 1.

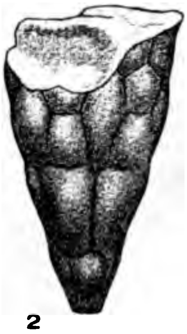
Fig. 4. Posterior view of the natural cast of the same individual. × 1.

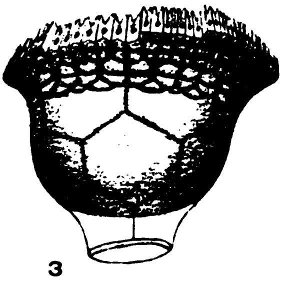
PLATYCRINUS AUGUSTA sp. nov., page 292.

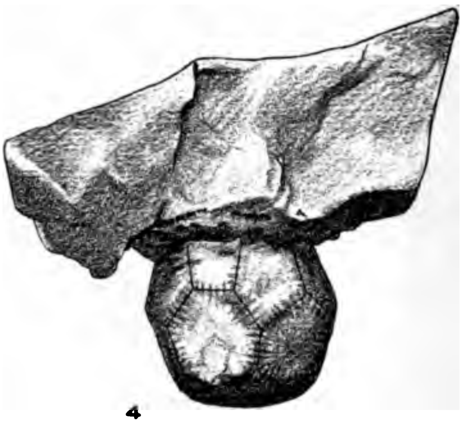
Figs. 5, 6. Lateral and basal views of a rubber impression of the natural mold of the type specimen. × 2.

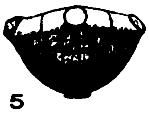
Fig. 7. Lateral view of the natural cast of the same individual. × 2.

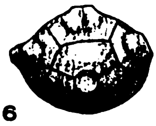

1


2


3


4


5


6

7

EXPLANATION OF PLATE XXXVII.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

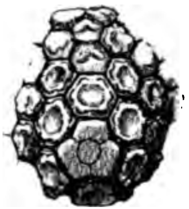
[illegible]

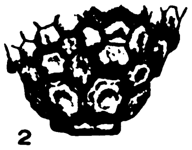
[illegible]

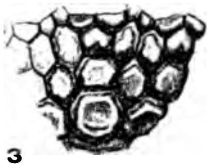
[illegible]

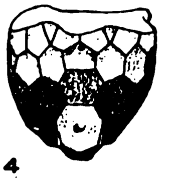
[illegible]

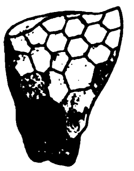
[illegible]

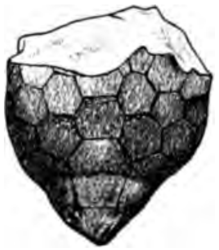

1

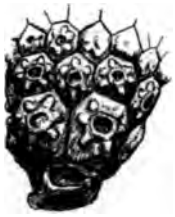

2

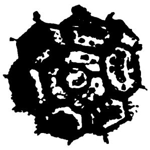

3

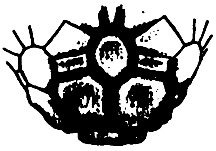

4

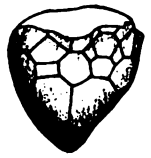

5

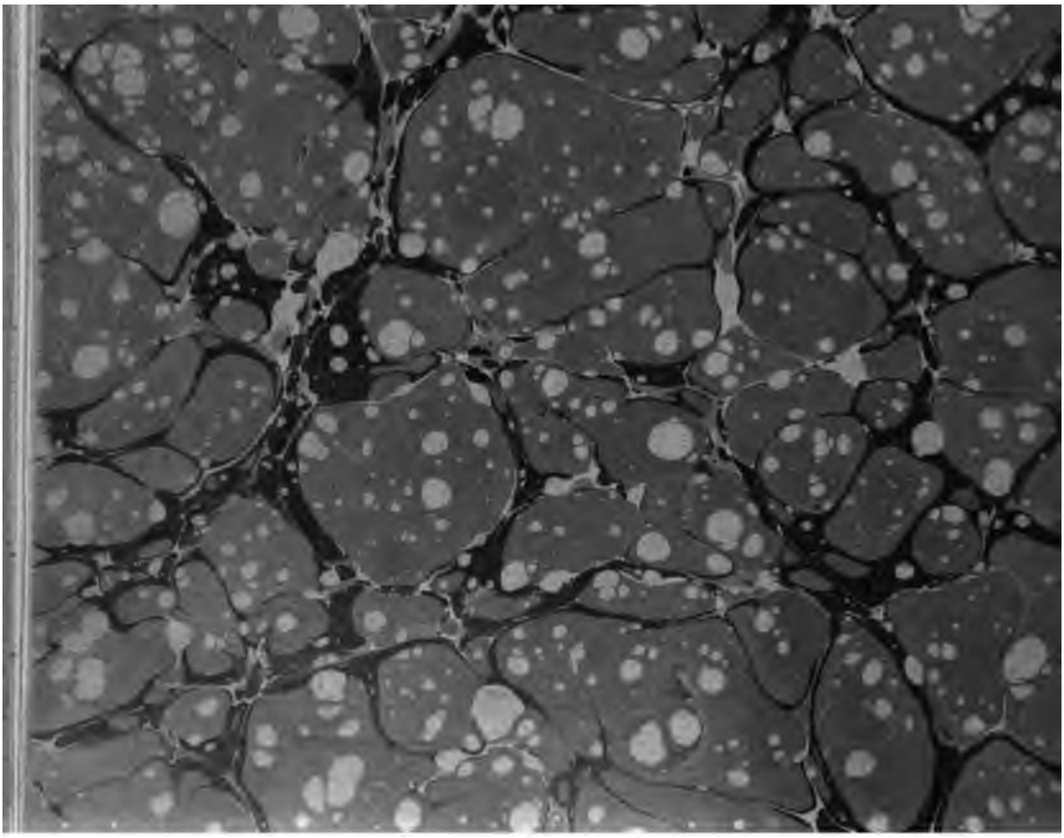

6

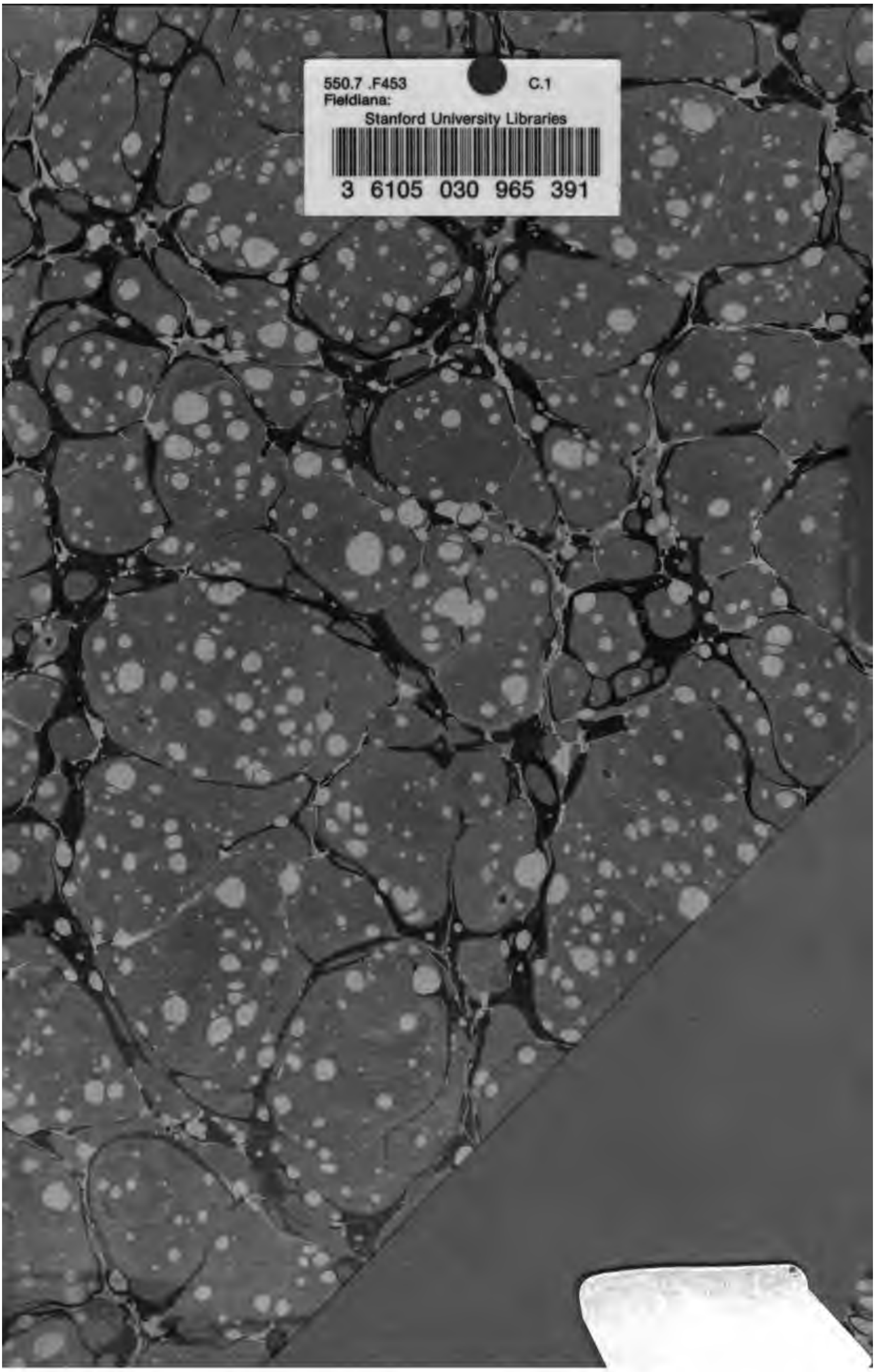

7


8

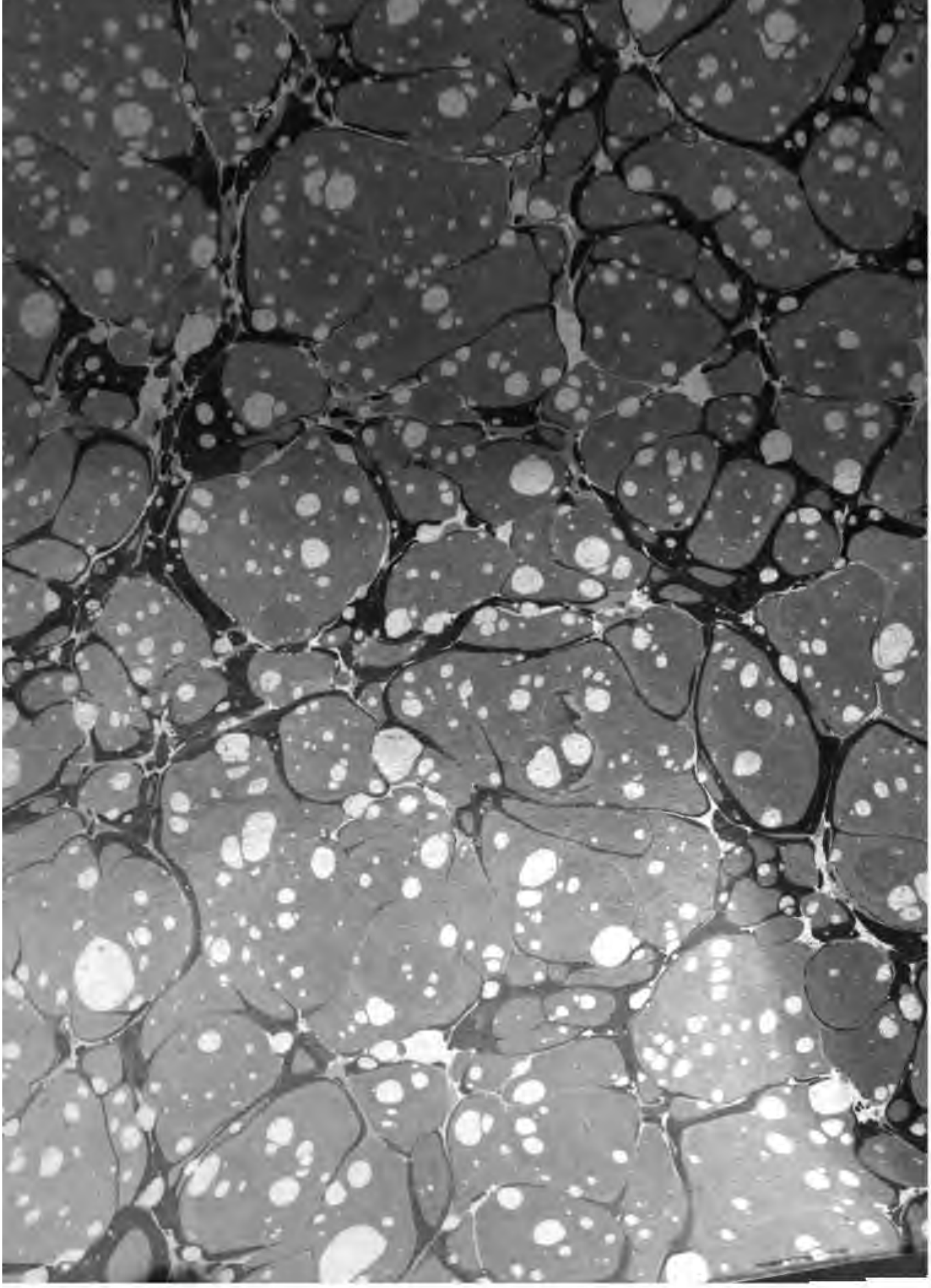

9


10





550.7 .F453 C.1
Fieldiana:
Stanford University Libraries
3 6105 030 965 391



550.7 .F453 C.1
Fieldiana:
Stanford University Libraries
3 6105 030 965 391